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The Impact of Adding Waste Pineapple Peel on the Process of Increasing Crude Oil Production

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Abstract

As the demand for petroleum continues to rise, it is still primarily met by fossil fuels and non-renewable energy sources. In addition, oil production, particularly in older fields, is declining, so this primary source cannot be relied upon in the future because its availability is diminishing. The EOR method utilized in this study is a chemical injection in the form of surfactant injection with the addition of refuse pineapple peel. This research employed a laboratory investigation employing AOS surfactant as a solution and brine of varying salinity levels (12,000 ppm and 5,000 ppm) and surfactant concentrations of 0.2% and 0.6%. Then, from the solution and the salinity, pineapple peel additives were added. At 30oC and 60oC, the density, viscosity, and interfacial tension of the AOS surfactant solution and the pineapple peel additive will be determined. The value to be used in this study is the lowest value based on the Interfacial Tension value in a 12,000 ppm Salinity solution and a 0.6% concentration of 18 dyne/cm, in the brine of 24.2 dyne/cm, and in a solution added with additives of 12,000 ppm and a 0.6% concentration yielding 15.9 dyne/cm. The recovery factor injection value for brine 12,000 ppm was 33.33 percent; for a salinity value of 12,000 ppm with a concentration of 0.6 percent, it was 42.01 percent; and for the additive value of pineapple peel and surfactant, a value of 44.26 percent was obtained. According to this study, the incorporation of pineapple peel waste has a positive effect on oil production.

Keywords:

Enhanced oil recovery; pineapple peel; IFT; surfactant.

1. Introduction

The need for petroleum energy continues to increase while the oil reserves continue to decrease. Global oil consumption is expected to increase by 1.6 million barrels per day (b/d) in 2023 from an average of 99.4 million b/d last year. It is estimated that petroleum consumption will grow by an additional 1.7 million b/d by 2024 (The U.S. Energy Information Administration (EIA), 2023). In addition, efforts to utilize waste are also being developed to reduce environmental pollution. In this paper, the author will present the results of research on the utilization of pineapple peel waste as an additive in surfactant solutions used in the enhanced oil recovery (EOR) process. In another article, to reduce waste that has an impact on the environment, mandarin orange peel waste has been used as an additive in the drilling mud filtration process. (Medved et al., 2023)

The surfactant used in this study was Alpha Olefin Sulphonate (AOS). Alpha Olefin Sulfonate (AOS) is an anionic surfactant with a negative charge on its charge head. The use of anionic surfactants is widely used in the EOR process because the use these surfactants has a relatively affordable price, show relatively low adsorption on sandstone rocks where the rock surface is opposing, its efficiency in reducing interfacial tension (IFT), as well as its stability at high temperatures (Belhaj et al., 2020) (Baviere et al., 1988).

According to (Baviere et al., 1988), the use of Alpha-Olein Sulfonate (AOS) surfactants in the industry can have positive effects as follows:

1. AOS has good salt tolerance, even in the presence of calcium ions. However, the addition of alcohol or an

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increase in temperature may be required to make it dissolve in the concentrated brine.

2. The main advantage of AOS is that they have optimal phase behavior (high solubility and low IFT parameters) from low to high temperatures in the high salinity range. Calcium ions have a particular effect, especially in low and medium salinity.
3. The screening test in the research conducted (Baviere et al., 1988) suggests the use of AOS surfactants as candidates for the use of EOR at low and high salinity, with a wide temperature range.

The use of surfactants to increase oil recovery factors has been studied for over 80 years. Surfactants are chemicals whose molecules always find a place between two fluids that do not mix. A surfactant or surface-active agent is a surface-active substance or molecule that acts on the surface, which can reduce the interfacial tension of two liquids that do not mix. The surfactant binds the two fluids together to form an emulsion, a water-soluble surfactant. (Zhou et al., 2019; Bera & Mandal, 2015).

The experiments included in other papers have provided some insight and evidence of the ability of chemical EOR to increase oil production in spite of failed projects in several areas. The utilization of local materials for surfactants and polymers has also been studied to reduce costs in the production process. Some chemicals come from several domestic sources, such as palm fruit and palm bunches (Abdurrahman et al., 2017). In addition, another article also describes the use of bagasse as a raw material for surfactant injection. (Imam et al., 2021)

Table 1: Chemical injection activities (Abdurrahman et al., 2017)

No	Field	Status	EOR Method	Year	EOR Production	Remarks
1	Minas	Pilot Project	Surfactant	2013	670 BOPD	Success
2	Kaji and Semoga	Field Trial	Surfactant	2014	10,996 BBL	Success
3	Meruap	Field Trial	Surfactant	2012	Gain Production 59-93 % from 2 wells	Success
4	Tanjung Field	Field Trial	ASP (Alkaline-Surfaktan-Polimer)	2013	225 BOPD dari 4 sumur	Success
5	Tanjung Field	Pilot Project	Polimer	2014	18 MSTB dari 169MSTB	Failed

Some uses of pineapple peel include making bioethanol (Arlianti, 2018), using pineapple peel as a hand sanitizer (Lubis & Maulina, 2020), using pineapple peel as an absorbent (Sofyan et al., 2020), and as a biosurfactant (Fabiola Carolina Gomes de Almeida et al., 2015). In this paper, the authors try to combine additive from pineapple peel which is added to type AOS surfactant with several salinities and then injected into the sample core saturated with brine and crude oil.

2. Laboratory Research

The series of experiments conducted are as follows:

1. Preparation of rock samples
2. Preparation of synthetic formation water (Brine)

Brine has a salt content of 5 grams, 12 grams, and 1000 ml of distilled water, equivalent to a salinity of 5000 ppm and 12,000 ppm.

3. Preparation of a surfactant solution. (5,000 ppm with 5 grams of NaCl and 12,000 ppm with 12 grams of NaCl and 1000 ml of distilled water at a concentration of 2% and 6% AOS surfactant solution).
4. Saturate cores with brine
5. Saturate the core with oil
6. Brine injection
7. Surfactant Injection

The materials used include:

1. Brine Salinity: 5,000 ppm and 12,000 ppm
2. Pineapple peel waste
3. AOS
4. Crude Oil
5. Rock samples

While the equipment used includes:

1. Digital scales
2. Tensiometer
3. Viscometer NDJ-8S
4. Magnetic Stirrer
5. Beaker
6. Measuring cup
7. Filter paper
8. Density meters

Before the injection process is carried out on the rock sample, the rock is measured for its porosity and permeability values. Meanwhile, density, viscosity, and IFT measurements were carried out to measure the physical properties of the fluid. The solution used in the injection stage is brine, brine added with AOS (surfactant solution), and surfactant solution added with pineapple peel waste additive.
The surfactant solution that was prepared in this study was made from the previously prepared brine and then mixed with AOS surfactant. Surfactants were added in this study with different concentration variations, so it can be concluded that the best value to be used is the interfacial tension value with surfactant concentrations of 2% and 6%. Adding pineapple peel additives is carried out constantly by adding 0.2 grams of all the total solutions used. The solution used is 40 ml. The temperature used in this study was measured at 30oC and 60oC.
The result of the injection process is that it can see that the oil that comes out of the core is considered the oil that is produced. The oil obtained is then expressed in the recovery factor (RF) percentage.

3. Results

a. Density

In this paper can be written several results from observations and measurements from the laboratory. Observations and measurements were made, among others, to obtain values for density, viscosity, IFT, and production of injection results in rock samples. This measurement was carried out using several different salinities, concentrations, and temperatures. Salinities used were 5000 ppm and 12000 ppm; surfactant concentrations used were 0.2% and 0.6% and tested at 30oC and 60oC. In Table 2 and Table 3 it can be seen the results of the density values.

Table 2: Measurement results of density values without the use of pineapple peel waste.

Surfactant Concentration, %	Salinity, ppm	Temperature, °C	Density, gr/cc

0.2	5000	30	0.9980
		60	0.9854
	12000	30	1.0030
		60	0.9908
0.6	5000	30	0.9987
		60	0.9863
	12000	30	1.0037
		60	0.9914

The results of density measurements without using pineapple peel waste are further described in Fig. 1 Based on the measurement results, the density value is affected by temperature, the concentration of AOS and the salinity value. The higher the concentration value, the smaller the density value and so is the salinity at a fixed concentration. In table1 it can be seen that the density value increases if the salinity is enlarged at a constant temperature.

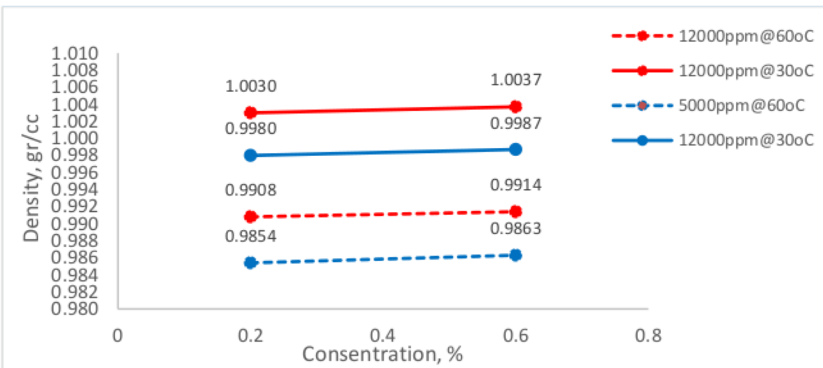


Figure 1: Measurement results of density values **without** the use of pineapple peel waste

Furthermore, in Table 3 and Figure 2 it can be seen the results of density measurements **with** the use of pineapple peel waste.

Table 3: Measurement results of density values **with** the use of pineapple peel waste

Surfactant Concentration, %	Salinity, ppm	Temperature, °C	Density, gr/cc
0.2	5000	30	0.9994
		60	0.9872
	12000	30	1.0087
		60	0.991
0.6	5000	30	1.0005
		60	0.9879
	12000	30	1.0095
		60	0.9921

The density value is affected by the concentration of AOS and the salinity value in a manner comparable to when pineapple peel waste is not used. In addition to being proportional to the concentration value (temperature and salinity held constant), the density value is also proportional to the concentration value. In contrast, the density value tends to diminish at various concentrations and high temperatures (salinity held constant).

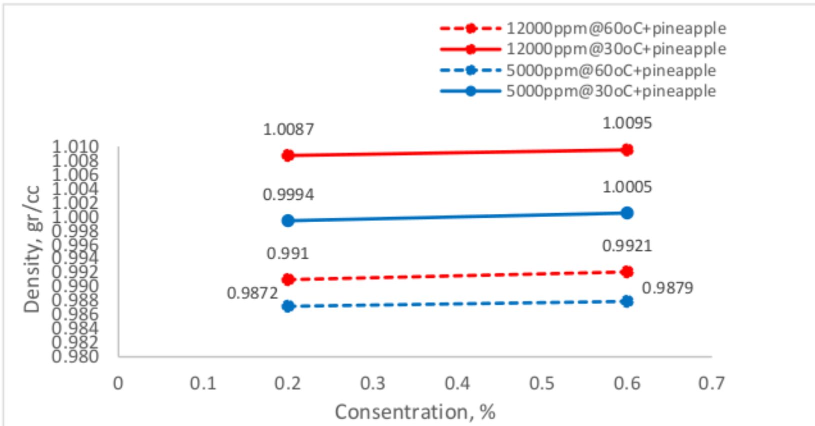


Figure 2: Measurement results of density values **with** the use of pineapple peel waste

b. Viscosity

The viscosity value is also affected by the concentration of AOS and the salinity value. The higher the concentration value, the greater the viscosity value, and so does the salinity at a fixed concentration; the more significant the viscosity value if the salinity is enlarged. However, the viscosity value tends to decrease due to the increase in temperature. Observations with and without using pineapple peel waste can be seen in Table 4 – 5 and can be described in Figures 3 – Figure. 4.

Table 4: Measurement results of viscosity values **without** the use of pineapple peel waste

Surfactant Concentration, %	Salinity, ppm	Temperature, °C	Viscosity, gr/cc
0.2	5000	30	2.8
		60	2.3
	12000	30	3.2
		60	3
0.6	5000	30	3
		60	2.5
	12000	30	3.9
		60	3.6

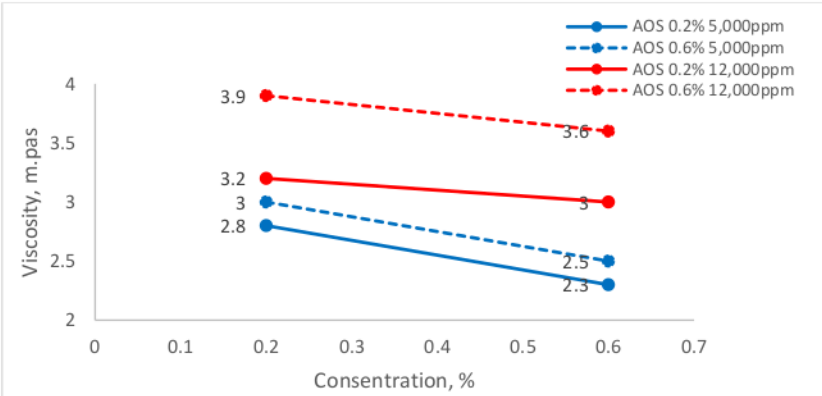


Figure 3: Measurement results of viscosity values **without** the use of pineapple peel waste

Similarly, the viscosity value of the surfactant solution containing pineapple peel waste is more significant if the concentration value is greater than the viscosity value, as is the salinity at a constant concentration, the higher the salinity, the greater the viscosity value. However, compared to the surfactant solution without pineapple peel waste, the viscosity of the solution containing pineapple peel waste is lower.

Table 5: Measurement results of viscosity values **with** the use of pineapple peel waste

Surfactant Concentration, %	Salinity, ppm	Temperature, °C	Viscosity, gr/cc
0.2	5000	30	2.2
		60	2.0
	12000	30	3
		60	2.8
0.6	5000	30	2.4
		60	2.3
	12000	30	3.3
		60	3.2

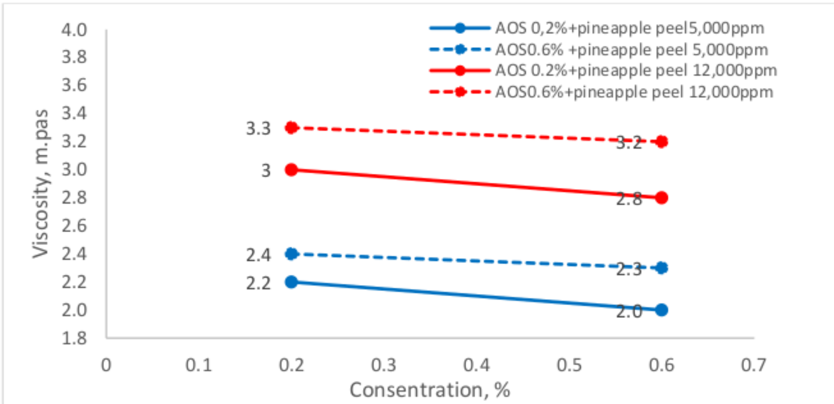


Figure 4: Measurement results of viscosity values **with** the use of pineapple peel waste

c. IFT Measurement of Surfactant Solutions Using Pineapple Peel Waste and No Waste

The value of interfacial tension is a value that is very influential in determining the value of oil acquisition. The lower the interfacial tension value, the more micellar concentration, which is useful for binding oil, so that more oil is bound and has implications for obtaining more oil. It is known from the measurements of the Interfacial tension values in table 6 and table 7, there is a difference between the two IFT values. It is known that the largest IFT value is known at a salinity of 5,000 ppm without the addition of AOS surfactant and the addition of pineapple peel additives. The lowest IFT value was obtained from a sample that had a salinity of 12,000 ppm, an AOS concentration of 6% and added pineapple peel additives.

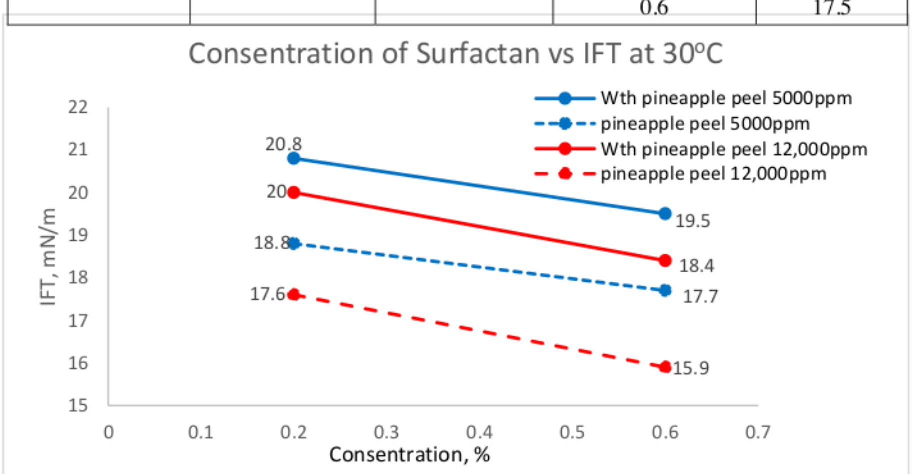
Table 6: Interfacial Tension at 30°C

Temperature	Solvent	Salinity,ppm	Concentration, %	IFT, mN/m
30°C	AOS (Without Pineapple Peel)	5000	0.2	20.8
			0.6	19.5
		12000	0.2	20
			0.6	19.4
	AOS + Poineapple Peel	5000	0.2	18.8
			0.6	17.7
		12000	0.2	17.6
			0.6	15.9

Figure 5: Interfacial Tension at 30°C

Table 7: Interfacial Tension at 60°C

Temperature	Solvent	Salinity,ppm	Concentration, %	IFT, mN/m
60°C	AOS	5000	0.2	19.2
			0.6	18.3
		12000	0.2	18
			0.6	17.5
	AOS + Poineapple Peel	5000	0.2	17.3
			0.6	15.8



		12000	0.2	16.3
			0.6	15.4

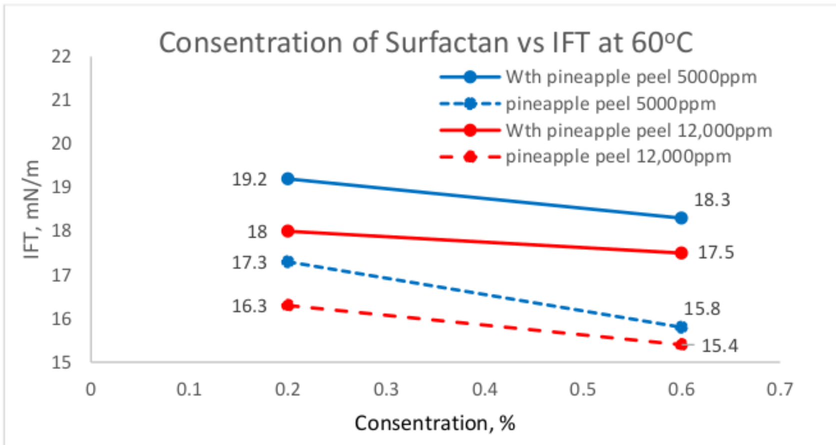


Figure 6: Interfacial Tension at 60°C

Based on observations, with an AOS concentration of 0.2% the IFT value was also affected by temperature. The higher the observation temperature, the lower the IFT value. The same thing happened at a concentration of 0.6%. The results of these observations can be seen in Figure 7 and Figure 8.

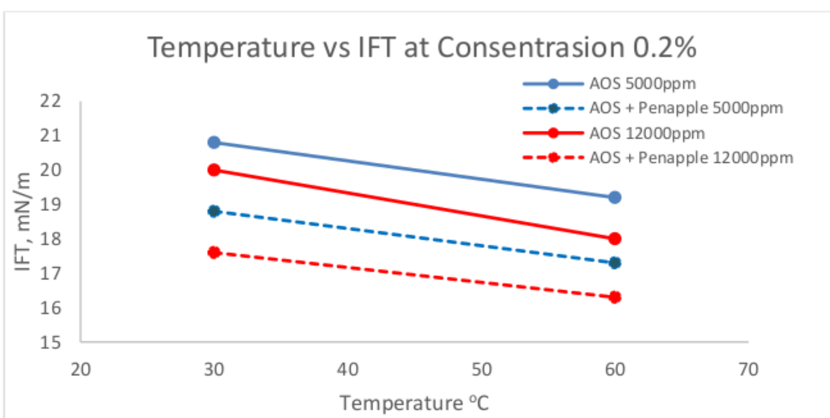


Figure 7: Interfacial Tension at concentration 0.2 %

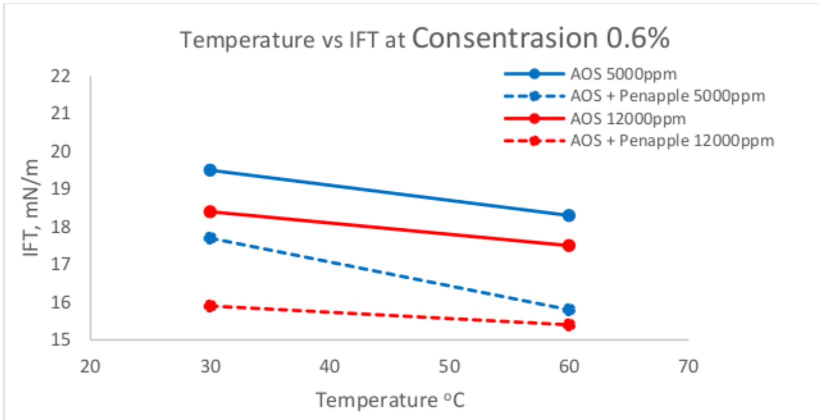


Figure 8: Interfacial Tension at concentration 0.6%

4. Discussion

The injection process was carried out three times using different salinities, as well as additional pineapple peel additives, core injection was carried out during the saturation process. The first injection used a brine solution with a salinity of 12,000, then used surfactant injection with a salinity of 12,000 ppm with an AOS solution concentration of 0.6%. In the final stage, namely injection of 12000 salinity solution, AOS concentration of 0.6% along with additional pineapple peel additives.

The process of injection of brine, surfactant, and surfactant plus additives is carried out separately, in the Z1 core, brine injection is carried out, while in the Z2 core, surfactant injection is carried out and in the Z3 core, AOS surfactant injection is carried out and additional pineapple peel additives.

Tabel 8 Results of injection at core sample

No	Core Sample	Pore Vol (cc)	OOIP (cc)	Swirr (cc)	NP (cc)
1	Z1	1.808	1.50	0.308	0.5
2	Z2	1.843	1.52	0.323	0.65
3	Z3	1.842	1.51	0.320	0.67

In Table 8 are the results of injection of brine, injection of surfactants and injection of surfactants plus pineapple peel additives in core samples.

The first injection process uses brine solution as an injection material. The choice of injection solution based on the low Interfacial Tension (IFT) value can be seen in table 3.5. Shows that the lowest IFT value is at a solution salinity of 12,000, then the brine will be used in the first injection, then the second injection is carried out using a solution with a salinity of 12,000 along with additional surfactant with a concentration of 0.6%, the last injection using a solution of 12,000 salinity with an AOS concentration of 0.6 % and additional pineapple peel additives.

It is known that the cumulative value of oil that comes out or the cumulative production (NP), Z1 core is obtained at 0.50 cc. This value is obtained based on the results of injection using brine. While the NP value in core Z2 was obtained by 0.65 cc, the addition of value between NP Z1 and NP Z2 was obtained by an addition of 0.15 cc because the addition of AOS surfactant factor affected the oil acquisition obtained, while the addition of NP value in core Z3 was obtained by 0.67 cc, the additional value was obtained by 0.02 cc to the value of Z3 after the addition of pineapple peel waste additive.

Based on the injection results, the Recovery Factor value in the current study sample is in Table 9, as follows:

Table 9 *Recovery Factor*

Solvent	Recovery Factor (%)	Sor (%)
Brine 12,000ppm	33.33	67.77
Brine 12,000ppm, AOS 0,6%	42.05	57.95
Brine 12,000ppm, AOS 0.6%, + Pineapple Peel	44.26	55.74

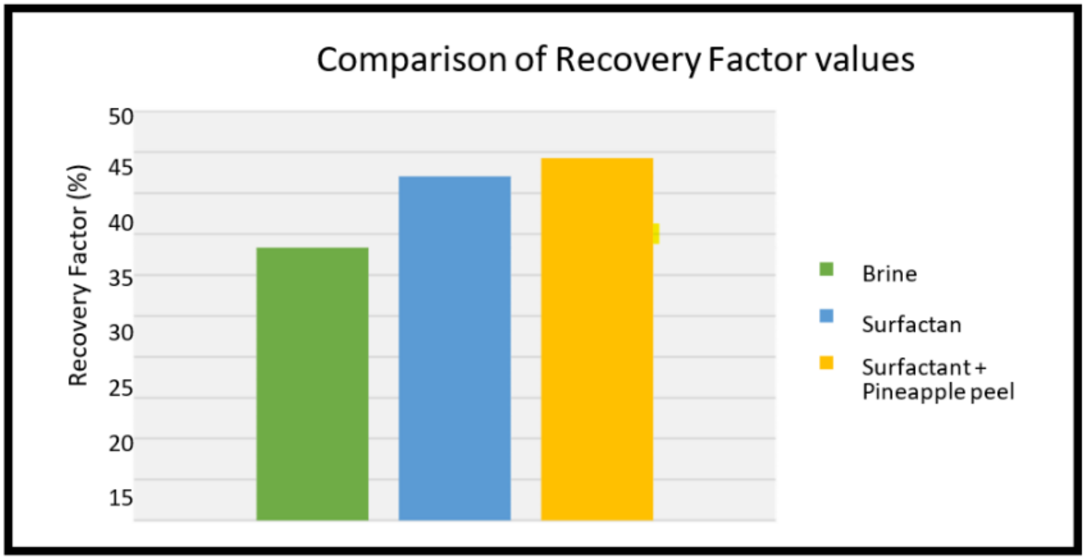


Figure 3.9 Comparison of Recovery Factor values

Figure 3.9 demonstrates that each sample subjected to the injection test showed an increase. There was an increase in the value of using brine with a salinity of 12,000 ppm and an AOS concentration of 0.6% due to the presence of surfactants, which contributed to an increase in oil production of 42.05%, then on the use of surfactants with a brine salinity of 12,000 ppm and an AOS concentration of 0.6 with the addition of pineapple peel additives. This demonstrates that adding pineapple rind to surfactants can increase oil recovery.

5. Conclusions

There are multiple conclusions that can be derived from this study.

1. AOS concentration, salinity, and temperature influence the values of viscosity, density, and IFT.
2. Viscosity, density, and IFT values are also affected by the addition of pineapple peel debris.
3. The addition of pineapple peel waste additive has a positive effect on oil recovery.
4. Obtaining oil by injection without and adding additives from pineapple peel waste yields a 33.03% and 44.26% recovery rate, respectively. There is a difference of 11.23% in the acquisition.

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Author's contribution

This article was written by **Samsol** (Master Degree, Lecturer in Reservoir Engineering with a focus on EOR research); **Pauhesti** (Lecturer, Master Degree, research focus on EOR); **Havid Pramadhika** (Lecturer, Master Degree, research focus on EOR and Oil and Gas Economics); **Muhammad Zainal Abidin** (Student of petroleum engineering); **Onnie Ridaliani** (Lecturer, Master Degree, expert in Reservoir Engineering); **Puri Wijayanti** (Lecturer, Master Degree, focus on research in the field of EOR and formation evaluation expertise); Sigit Rahmawan (PhD Candidate in Petroleum Engineering) sand **Asri Nugrahanti** (Professor and Lecturer, formation evaluation expertise). This research was chaired by Samsol. Samsol plays a role in providing ideas, making concept designs, and conducting laboratory tests. Pauhesti, Havid Pramadhika, and Muhammad Zainal Abidin assisted research in the laboratory. The role of Pauhesti and Havid Pramadhika is to prepare materials and equipment needed during laboratory tests. Onnie Ridaliani and Puri Wijayanti analyzed laboratory examination results then the results of the analysis were reviewed by Sigit Rahmawan and Asri Nugrahanti.

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