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The Impact of Adding Waste Pineapple Peel on the EOR Process to Increase Crude Oil Production

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Abstract

As the demand for energy 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. The enhanced oil recovery (EOR) method utilized in this study is surfactant injection with the addition of waste pineapple peel. The experiment was carried out in a controlled laboratory setting, using surfactant and brine solutions with salinities of 5,000 ppm and 12,000 ppm, respectively. The concentration range of alpha olefin sulfonate (AOS) surfactant employed ranged from 0.2% to 0.6% (2×10^{-6} m³ and to 0.6% from 1×10^{-3} m³). The solution was tested at two different temperatures, specifically 30°C and 60°C. The solution was tested with the addition of the pineapple peel and without pineapple peel. The density, viscosity, and interfacial tension of the two solutions were determined using laboratory measurements. The subsequent procedure involves the injection of the core sample in order to determine the oil recovery factor. The interfacial tension (IFT) values obtained were 17.5 mN/m in the absence of additives and 15.4 mN/m in the presence of additives derived from pineapple peel. The recovery factor for a solution with a salinity of 12,000 ppm and a concentration of 0.6% is determined to be 42.01%. Additionally, the recovery factor for a surfactant solution with the addition of pineapple peel is found to be 44.26%. Based on the findings of this study, the utilization of waste pineapple peel demonstrates a beneficial impact on the process of oil production.

Keywords:

Enhanced oil recovery (EOR); pineapple peel; interfacial tension (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 (bbl/d) in 2023 from an average of 99.4 million bbl/d last year. It is estimated that petroleum consumption will grow by an additional 1.7 million bbl/d by 2024 (**EIA, 2023**). In another article, to reduce waste that has an impact on the environment, waste mandarin orange peel has been used as an additive in the drilling mud filtration process (**Medved et al., 2023**). 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**).

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Surfactant flooding is a chemically enhanced oil recovery technique that is employed to decrease the interfacial tension between oil and water, thereby facilitating the movement of remaining oil into production wells. Choosing an appropriate surfactant for the reservoir conditions is a significant challenge during the surfactant feeding procedure. The cost of an enhanced oil recovery process is mostly influenced by surfactants, and the depletion of surfactants results in significant financial setbacks. This procedure may experience a substantial reduction in surfactant concentration as a result of its adsorption into the porous medium. The primary elements influencing surfactant adsorption on reservoir rocks are surfactant concentration, salinity, temperature, and pH. The majority of the research has been carried out under conditions of low temperature and low salinity. The deployment of surfactant flooding in high-temperature and high-salinity settings has been limited due to the challenges involved. This work specifically examines the reviews of studies completed on surfactant adsorption on various types of reservoir rocks, considering different surfactant types and reservoir circumstances. It also investigates the impact of surfactant concentration, salinity, temperature, and pH on surfactant adsorption (**Fatih et al., 2019**).

The surface tension and emulsification index measurements demonstrated a beneficial impact from an alkaline pH and a significant resistance to the ionic strength of the product. The solubility dropped by almost 50% for alkaline pH or high salinity levels over 10%. The weight solubilization ratio exhibited a negative correlation with the escalating biosurfactant concentrations. The inclusion of the biosurfactant increased the solubility of naphthalene in water in all instances (**Abouseoud et al., 2010**).

The surfactant used in this study was alpha olefin sulfonate (AOS). AOS is an anionic surfactant with a negative charge on its charge head. Anionic surfactants are widely used in the EOR process because these surfactants have a relatively affordable price, show relatively low adsorption on sandstone rocks where the rock surface is opposing, exhibit efficiency in reducing interfacial tension, and they are stable at high temperatures (**Belhaj et al., 2020**).

According to (**Baviere et al., 1988**), the use of alpha olefin sulfonate 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 increase in temperature may be required to make it dissolve in concentrated brine.
2. The main advantage of AOS is that it has 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 suggests the use of AOS surfactants as candidates for the use of EOR at low and high salinity, with a wide temperature range.

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.

Abdurahman's research explores the past application of the enhanced oil recovery method. The report also examines the accomplishments and limitations of the utilized enhanced oil recovery technique. The article also explores the application of surfactants and co-surfactants to improve the extraction of hydrocarbons (**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**).

Some uses of pineapple peel include making bioethanol (**Arlianti, 2018; Casabar et al., 2019**), using pineapple peel as a hand sanitizer (**Lubis & Maulina, 2020**), using pineapple peel as an absorbent (**Sofyan et al., 2020**), and as a biosurfactant (**Gomes de Almeida et al., 2015**). In this paper, the authors try to combine pineapple peel as an additive and a type AOS surfactant with several salinities which are then injected into the sample core saturated with brine and crude oil.

Conventional methods for surfactant evaluation in EOR published in the literature by different authors were used to test the synthesized surfactant (**Flaaten, 2010; Puerto, 2012; Lu, 2014; Ojo, 2018**). Numerous variations of enhanced oil recovery techniques have emerged with the objective of recovering a portion of the remaining oil.

Chemical flooding has gained popularity due to the emergence of newly developed surfactants and their significant properties, which effectively mitigate the capillary pressures responsible for trapping oil within the reservoir's pores (**Zargartalebi, 2015**).

Surfactant flooding has emerged as a prominent chemical enhanced oil recovery approach, demonstrating notable efficacy in augmenting oil recovery rates (**Temiouwa, 2018**). The lowering of interfacial tension between the aqueous phase (brine and surfactant) and the oleic phase (crude oil) is a significant factor in chemical flooding, as noted by **Bera & Mandal (2015)** and **Gao (2013)**.

Chemical flooding is considered to possess significant promise among many strategies, particularly in situations where water injection facilities are accessible and thermal or gas methods are impractical. Scientists have found that using water-soluble polymers, surfactants, and alkalis in chemical flooding can help get more oil out of onshore sandstone oil fields (**Green & Willhite, 2018**).

Ultimately, the success of the EOR method relies heavily on the extent of fluid saturation within the reservoir. Fluid saturation, which refers to the quantity of fluid contained inside the pores of a reservoir system, significantly contributes to the enhancement of oil output (**Tummuri, 2022**). In order to assess the efficacy of this approach, it is imperative to conduct simulation experiments with models or equipment that are specifically designed to replicate real-world settings (**Vulin et al., 2018, Ranton et al., 2020**). In addition to fluid saturation, the use of the enhanced oil recovery (EOR) strategy must also take into account the permeability and wettability properties of the reservoir. In order to enhance oil extraction, it is crucial to comprehend the methods by which immiscible fluids are transferred in such circumstances. Fluid flow study demonstrates that the occurrence of the viscous fingering phenomena is a result of viscous instability, which is affected by the mobility of the fluid and capillary forces. Furthermore, the presence of diverse domains inside porous materials also significantly influences the formation of fingering patterns (**Shiri, & Shiri, 2021**).

In addition, efforts to utilize waste are also being developed to reduce environmental pollution. In this paper, the authors will present the results of research on the utiliza-

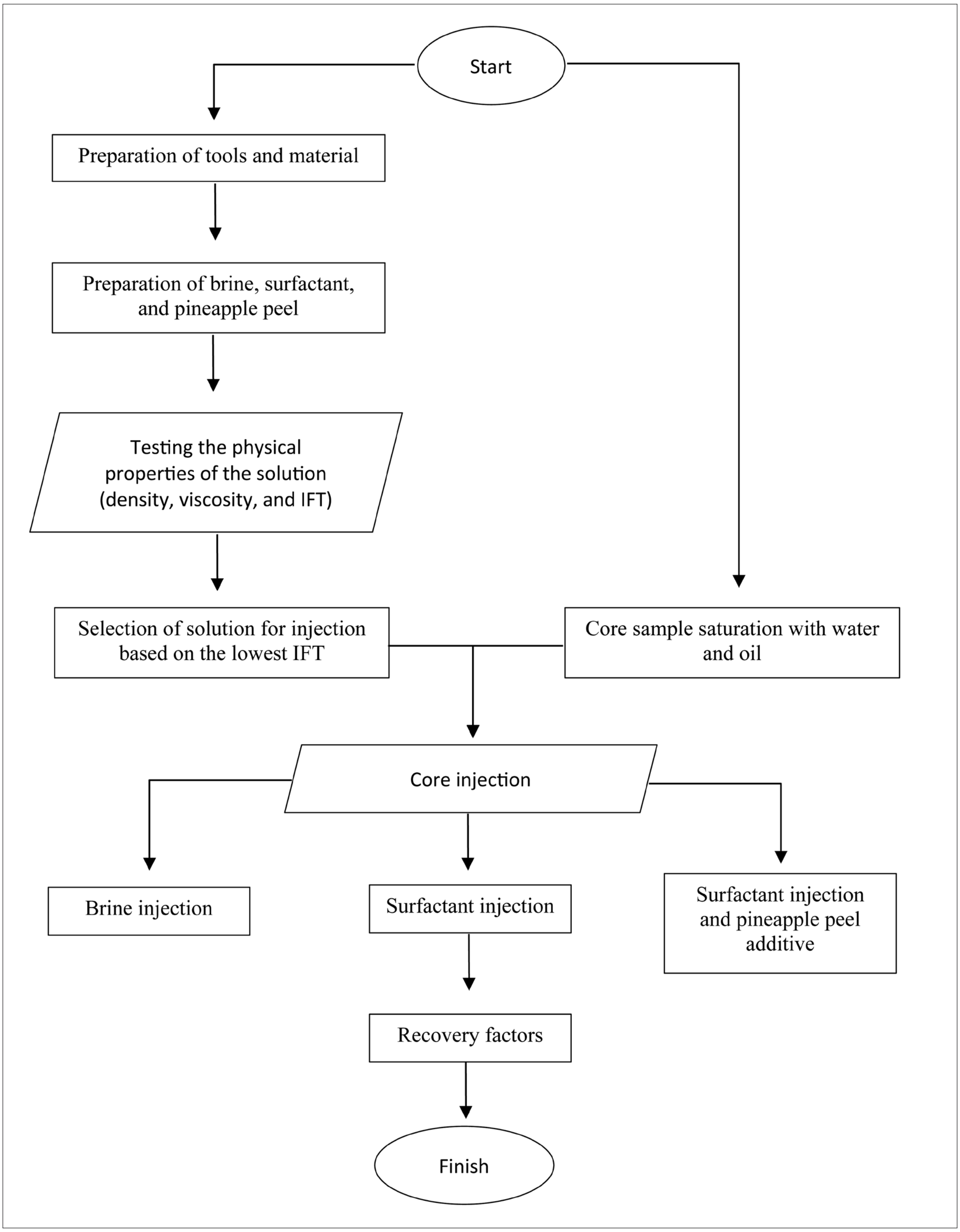

Figure 1: Research flow chart

tion of waste pineapple peel as an additive in surfactant solutions used in the enhanced oil recovery process.

2. Laboratory research

The study was carried out in a controlled laboratory setting. This study employs a variety of equipment and materials that have been selected and deemed appropriate for the research. The research findings are succinctly presented in the flowchart depicted in **Figure 1**.

The study was conducted in a controlled laboratory setting, utilizing the equipment and materials given for the research. The objective of this study is to utilize a core sample of the berea type. Subsequently, the dimensions of the aforementioned core are assessed in order to ascertain the pore volume it possesses. Additionally, oil samples extracted from one of the oil fields were utilized in this study. The subsequent step involves the production of a synthetic brine solution. Two different brine solutions were utilized in the experiment, with masses of 5×10^{-3} kg and 12×10^{-3} kg, respectively. Additionally, a volume of 1×10^{-3} m^3 of distilled water was employed. The salinity of this brine solution is equivalent to 5,000 parts per million (ppm) and 12,000 ppm.

The subsequent procedure involves the preparation of a surfactant solution. The surfactant solution was prepared by including AOS with a concentration of 0.2% (2×10^{-6} m^3 out of a total volume of 1×10^{-3} m^3) and 0.6% (6×10^{-6} m^3 out of a total volume of 1×10^{-3} m^3) in the solution. The concentration of surfactant was dissolved in brine solutions with concentrations of 5,000 ppm and 12,000 ppm, which had been prepared in advance. Indeed, the present study employed a supplementary component derived from pineapple peel, which was subjected to extraction procedures and then combined with a surfactant solution.

Table 1: Density measurements obtained without utilizing waste pineapple peel

Surfactant Concentration (%)	Salinity (ppm)	Temperature (°C)	Density (kg/m³)
0.2	5000	30	998.0
		60	985.4
	12000	30	1003.0
		60	990.8
0.6	5000	30	998.7
		60	986.3
	12000	30	1003.7
		60	991.4

Before the injection process was carried out on the rock sample, the rock was 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 with the addition of surfactant solution, and a surfactant solution with waste pineapple peel as an 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 0.2% and 0.6%. Adding pineapple peel additives is carried out constantly by adding 0.2×10^{-3} kg of all the total solutions used. The solution used is 4×10^{-5} m^3. The temperature used in this study was measured at 30°C and 60°C.

The result of the injection process is 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 percentage.

3. Results and discussion

This study has successfully discovered a number of characteristics, namely density, viscosity, and interfacial tension. The data measurement involves the utilization of a temperature range spanning from 30°C to 80°C, together with a salinity range of 5,000 ppm to 12,000 ppm.

3.1. Density

This paper will discuss several laboratory findings and measurements. Various observations and measurements

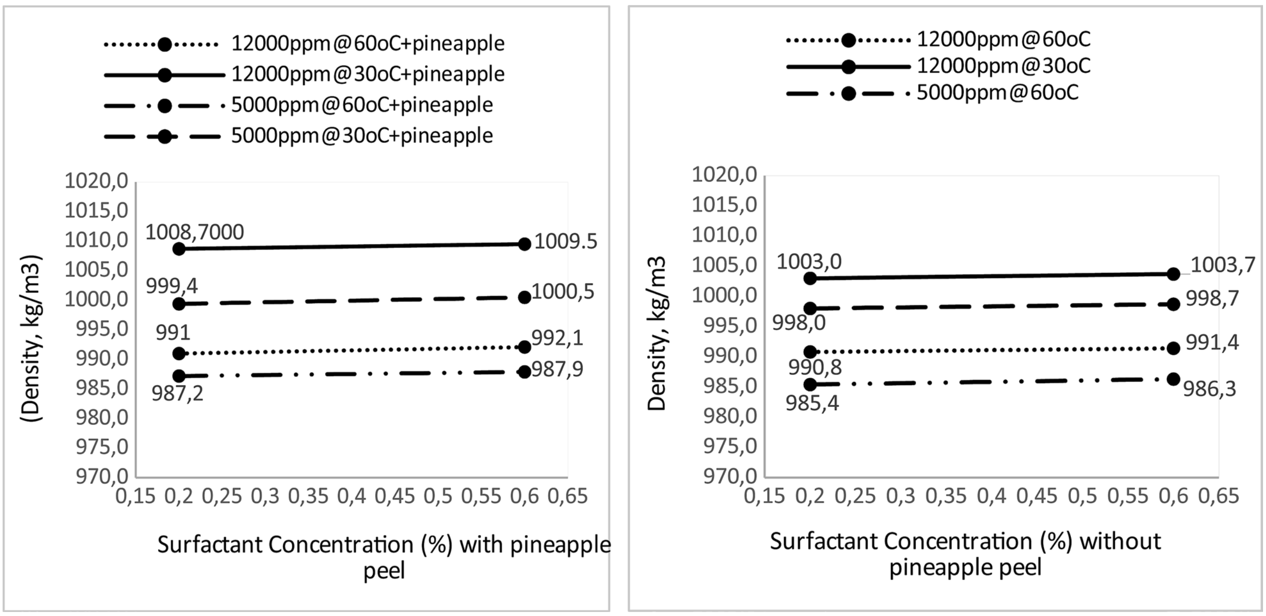

Figure 2: Density measurements obtained without utilizing waste pineapple peel

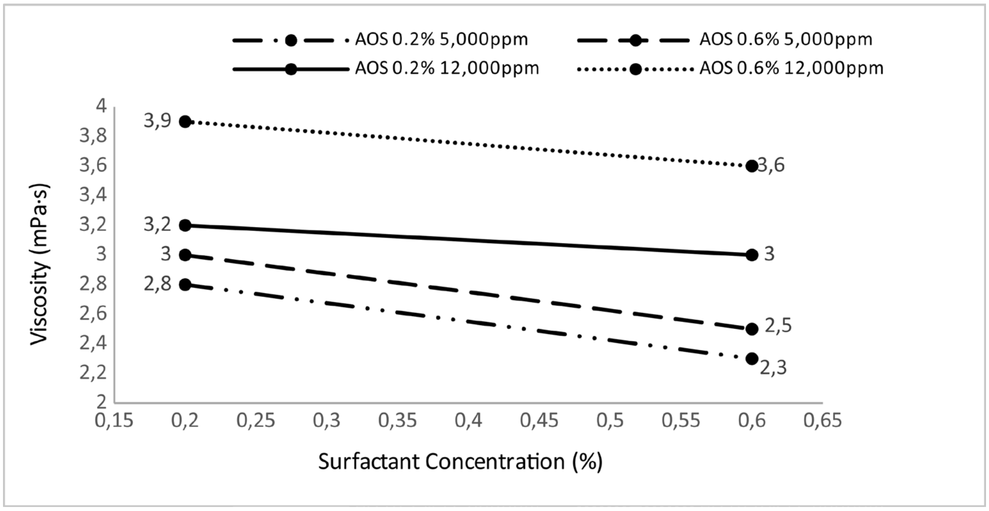

Figure 3: Viscosity measurements obtained without utilizing waste pineapple peel

were conducted to get data on density, viscosity, IFT, and injection performance in rock samples. The measurement was conducted using various salinities, concentrations, and temperatures. The salinities employed were 5,000 ppm and 12,000 ppm, while the surfactant concentrations utilized were 0.2% and 0.6%. These conditions were examined at temperatures of 30°C and 60°C. The density values are presented in **Table 1**.

The density tests conducted without utilizing waste pineapple peel are presented in **Figure 2**. The results indicate that the density value is influenced by temperature, the concentration of AOS, and the salinity value, both with and without the inclusion of waste pineapple peel. As the concentration value increases, the density value decreases, resulting in a corresponding decrease in salinity at a constant concentration.

3.2. 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 with salinity at a fixed concentration, the viscosity value is more significant if the salinity is increased. However, the viscosity value tends to decrease due to an increase in temperature. Observations with and without using waste pineapple peel can be described in **Figure 3** and **Figure 4**.

Similarly, the viscosity value of the surfactant solution containing waste pineapple peel 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 waste pineapple peel, the viscosity of the solution containing waste pineapple peel is lower.

The results of the observations **Table 2** that have been made can be seen clearly in **Figure 4**, which shows the change in the viscosity value for the addition of surfactant concentration. As the concentration increases, there is a corresponding decrease in viscosity. Furthermore, it should be noted that salinity exerts an influence on the viscosity measurement, whereby an increase in salinity corresponds to an increase in the viscosity of the solution.

Table 2: Viscosity measurements were obtained from waste pineapple peel

Surfactant Concentration (%)	Salinity (ppm)	Temperature (°C)	Viscosity (mPa·s)
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

3.3. Interfacial tension measurement of surfactant solutions using waste pineapple peel 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 results in **Table 3**, there are a differences between the two IFT values. It is known that the largest interfacial tension 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 interfacial

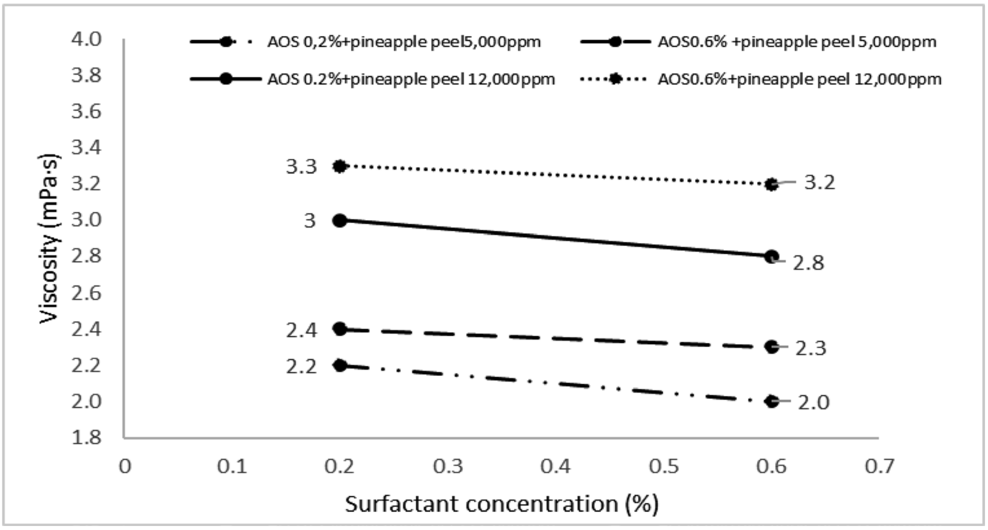

Figure 4: Viscosity measurements using waste pineapple peel

Table 3: Interfacial Tension at 30°C and 60°C

Temperature	Solvent	Salinity (ppm)	Concentration (%)	IFT (mN/m)
30°C	AOS	5000	0.2	20.8
		5000	0.6	19.5
		12000	0.2	20.0
		12000	0.6	19.4
	AOS + Pineapple Peel	5000	0.2	18.8
		5000	0.6	17.7
		12000	0.2	17.6
		12000	0.6	15.9
60°C	AOS	5000	0.2	19.2
		5000	0.6	18.3
		12000	0.2	18.0
		12000	0.6	17.5
	AOS + Pineapple Peel	5000	0.2	17.3
		5000	0.6	15.8
		12000	0.2	16.3
		12000	0.6	15.4

tension value was obtained from a sample that had a salinity of 12,000 ppm, an AOS concentration of 6% and the addition of pineapple peel.

Based on the IFT values in **Table 3**, the selection for the injection process was made. It 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.

4. Recovery factor

The injection process was carried out three times using different salinities, as well as additional pineapple

Tabel 4: Results of injection at core sample

No	Core Sample	Pore Vol (10^{-6} m^3)	OOIP (10^{-6} m^3)	Swirr (10^{-6} m^3)	NP (10^{-6} m^3)
1	Z1	1.808	1.50	0.308	0.50
2	Z2	1.843	1.52	0.323	0.65
3	Z3	1.842	1.51	0.320	0.67

Table 5: *Recovery Factor*

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

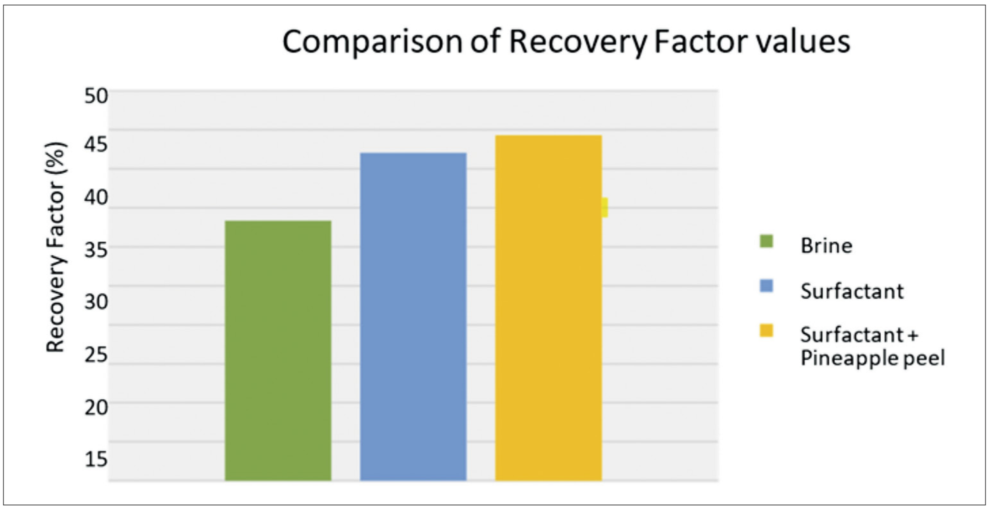

Figure 5: Comparison of Recovery Factor values

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 the 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 with additional pineapple peel additives.

Table 4 shows the results of the injection of brine, the injection of surfactants and the 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 5**.

It is known that the cumulative value of oil that comes out or the cumulative production (NP), Z1 core is obtained at 0.5×10^{-6} m^3. This value is obtained based on the results of the injection using brine. While the NP value in core Z2 was obtained by 0.65×10^{-6} m^3, the addition of value between NP Z1 and NP Z2 was obtained by an addition of 0.15×10^{-6} m^3 because the addition of AOS surfactant factor affected the oil acquisition obtained, while the addition of NP value in core Z3 was obtained by 0.67×10^{-6} m^3, the additional value was obtained by 0.02×10^{-6} m^3 to the value of Z3 after the addition of waste pineapple peel. Based on the injection results, the recovery factor value in the current study sample is in **Table 5**, as follows:

Figure 5 demonstrates that each sample subjected to the injection test showed an increase in the recovery factor. 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 of 44.26%. This demonstrates that adding pineapple peel to surfactants can increase oil recovery.

5. Conclusions

Based on the contextual framework of this research, the utilization of AOS surfactants in conjunction with the incorporation of waste pineapple peel can yield various findings. The findings of this study indicate that alterations in the concentration of AOS, salinity levels, and temperature exert a substantial influence on the characteristics of viscosity, density, and interfacial tension. Furthermore, the application of pineapple peel extract has shown encouraging outcomes in modulating these characteristics, leading to a reduction in density and viscosity measurements within the temperature interval of 30°C to 60°C, alongside a concurrent decrease in interfacial tension. The incorporation of this additive yields a favorable effect on oil recovery, leading to a substantial augmentation in comparison to the absence of the additive. This finding demonstrates that the incorporation of waste pineapple peel as an additive has the potential to enhance oil yield by 11.23%.

6. References

Abdurrahman, M., Permadi, A. K., Bae, W. S., & Masduki, A. (2017): EOR in Indonesia: Past, present, and future. International Journal of Oil, Gas and Coal Technology, 16(3), 250–270. https://doi.org/10.1504/IJOGCT.2017.087024

Abouseoud, M., Yataghene, A., Amrane, A., & Maachi, R. (2010): Effect of pH and salinity on the emulsifying capacity and naphthalene solubility of a biosurfactant produced by Pseudomonas fluorescens. Journal of Hazardous Materials, 180(1–3), 131–136. https://doi.org/10.1016/j.jhazmat.2010.04.003

Arlianti, L. (2018): Bioetanol Sebagai Sumber Green Energy Alternatif yang Potensial Di Indonesia. Unistek, 5(1), 16–22. https://doi.org/10.33592/unistek.v5i1.280

Baviere, M., Bazin, B., & Noik, C. (1988): Surfactants for Eor: Olefin Sulfonate Behavior At High Temperature and Hardness. SPE Reservoir Engineering (Society of Petroleum Engineers), 3(2), 597–603. https://doi.org/10.2118/14933-PA

Bera, A., & Mandal, A. (2015): Microemulsions: a novel approach to enhanced oil recovery: a review. In Journal of Petroleum Exploration and Production Technology. https://doi.org/10.1007/s13202-014-0139-5

Casabar, J. T., Unpaprom, Y., & Ramaraj, R. (2019): Fermentation of pineapple fruit peel wastes for bioethanol production Fermentation of pineapple fruit peel wastes for bioethanol production. December. https://doi.org/10.1007/s13399-019-00436-y

Gomes de Almeida, F. C., Alves de Lima e Silva, T., Garrard, I., Sarubbo, L. A., De Campos-Takaki, G. M., & Tambourgi, E. B. (2015): Optimization and Evaluation of Biosurfactant Produced by Pantoea sp. Using Pineapple Peel Residue, Vegetable Fat and Corn Steep Liquor. Journal of Chemistry and Chemical Engineering, 9(4). https://doi.org/10.17265/1934-7375/2015.04.005

Fatih, A., Khaled, B., Elraies, A., Mohammad, S., Nazliah, M., & Zulkifli, N. (2019): The effect of surfactant concentration , salinity, temperature, and pH on surfactant adsorption for chemical enhanced oil recovery : a review. Journal of Petroleum Exploration and Production Technology, 0123456789. https://doi.org/10.1007/s13202-019-0685-y

Flaaten, A. K. (2010): Alkaline/surfactant/polymer chemical flooding without the need for soft water. SPE Journal, 15(01), 184–196. https://doi.org/10.2118/116754-PA

Gao, B. &. M. Sharma, Mukul. (2013): A family of alkyl sulfate gemini surfactants. 2. Water-oil interfacial tension reduction. Journal of colloid and interface science, 407, 375–381. https://doi.org/10.1016/j.jcis.2013.06.066

Green, D. W. and Willhite, G. P. (2018): Enhanced Oil Recovery, second edition. Richardson, Texas, USA. Society of Petroleum Engineers. https://doi.org/10.2118/9781613994948.

Imam, R., Setiati, R., & Sitaresmi, R. (2021): Sodium lignosulfonate surfactant microemulsion for light crude oil Indonesia. IOP Conference Series: Materials Science and Engineering, 1098(6), 062025. https://doi.org/10.1088/1757-899x/1098/6/062025

Lubis, A. W., & Maulina, J. (2020): Pemanfaatan Ekstrak Kulit Nanas (Ananas comosus L.) Dalam Pembuatan Hand Wash Sebagai Antibakteri. BEST Journal (Biology Education, Sains and Technology), 3(1), 70–75. https://doi.org/10.30743/best.v3i1.2438

Lu, J. B. (2014). Novel large-hydrophobe alkoxy carboxylate surfactants for enhanced oil recovery. SPE Journal, 19(06), 1–024. https://doi.org/10.2118/154261-PA

Medved, I., Pašić, B., & Mijić, P. (2023): The influence of mandarin peel powder on filtration properties and temperature stability of water-based drilling mud. Rudarsko-Geološko-Naftni Zbornik, 53–64. https://doi.org/10.17794/rgn.2023.2.3

Ojo, T. O. (2018). Nano Augmented Biosurfactant Formulationfor Medium Oil Reservoirs. SPE-Nigeria Annual International Conference and Exhibitionheld at Lagos, SPE-193485-MS. https://doi.org/10.2118/193485-MS

Puerto, M. H. (2012): Surfactant systems for EOR in high-temperature, high-salinity environments. SPE journal, 17(01), 11–19. https://doi.org/10.2118/129675-PA

Rantan, R., Djumantara, M., & Samsol, S. (2020): Pemilihan Pola Injeksi Air Dengan Menggunakan Simulasi Reservoir Untuk Optimasi Produksi Lapangan 'R.' PETRO:Jurnal Ilmiah Teknik Perminyakan, 9(2), 81. https://doi.org/10.25105/petro.v9i2.6554

Sofyan, A., Kurniaty, N., & Wisnuwardhani, H. A. (2020): Pembuatan Dan Karakterisasi Karbon Aktif Dari Kulit Nanas (Ananas Comosus (L.) Menggunakan Aktivator H2SO4. Jurnal Farmasi, 6(2), 768–773.

Temiouwa, O; et al. (2018): Nano Augumented Biosurfactant Formulation for Oil Recovery in Medium Oil Reservoirs. In SPE Nigeria Annual International Conference and Exhibition. Society of Petroleum Engineers. https://doi.org/10.2118/193485-MS

Tummuri, N. V. P.; Devarapu, S. R.; Govindarajan, S. K. (2022): Comparative analysis on the impact of water saturation on the performance of in-situ combustion. Rudarsko-geološko-naftni zbornik, 167-175. https://doi.org/10.17794/rgn.2022.4.14

Vulin, D.; et al (2018): Slim-tube simulation model for carbon dioxide enhanced oil recovery. Rudarsko-geološko-naftni zbornik, 37-48. https://doi.org/10.17794/rgn.2018.2.4

Yousef, Shiri., & Alireza, Shiri. (2021): Numerical Investigation of Fluid Flow Instabilities in Pore-scale with Heterogeneities in Permeability and Wettability. Rudarsko-geološko-naftni zbornik, 143-156. https://doi.org/10.17794/rgn.2021.3.10

Zargartalebi, M. K. (2015): Enhancement of surfactant flooding performance by the use of silica nanoparticles, 143, 21-27. https://doi.org/10.1016/j.fuel.2014.11.040

Zhou, Y., Yin, D., Chen, W., Liu, B., & Zhang, X. (2019): A comprehensive review of emulsion and its field application for enhanced oil recovery. In Energy Science and Engineering. https://doi.org/10.1002/ese3.354

SAŽETAK

Utjecaj dodavanja otpadne kore ananasa u svrhu povećanja proizvodnje sirove nafte tijekom procesa povećanja iscrpka nafte

Kako potražnja za energijom i dalje raste, ona se i dalje primarno zadovoljava fosilnim gorivima i neobnovljivim izvorima energije. Osim toga, proizvodnja nafte, osobito na starijim poljima, opada. Metoda povećanja iscrpka nafte (engl. *Enhanced Oil Recovery*, EOR) korištena u ovoj studiji jest utiskivanje surfaktanta s dodatkom otpadne kore ananasa. Eksperiment je proveden u kontroliranim laboratorijskim uvjetima korištenjem surfaktanta i slane vode saliniteta 5000 ppm odnosno 12 000 ppm. Raspon koncentracija korištenoga surfaktanta (alfa-olefin sulfonat, AOS) bio je od 0,2 % do 0,6 % (2×10^{-6} m^3 i do 0,6 % od 1×10^{-3} m^3). Ispitivanje otopine provedeno je na dvjema različitim temperaturama, točnije 30 °C i 60 °C. Otopina je ispitana s dodatkom kore ananasa i bez kore ananasa. Laboratorijskim mjerenjima određene su gustoća, viskoznost i međufazna napetost navedenih dviju otopina. Kako bi se utvrdio iscrpak nafte, navedene otopine utisnute su u uzorak jezgre. Dobivene vrijednosti međufazne napetosti (engl. *interfacial tension*, IFT) bile su 17,5 mN/m bez prisustva aditiva (kore ananasa) i 15,4 mN/m u slučaju otopine u koju je dodana kora ananasa. Iscrpak nafte u slučaju otopine saliniteta 12 000 ppm i koncentracijom surfaktanta 0,6 % iznosio je 42,01 %. Nadalje, utvrđeno je da iscrpak nafte u slučaju otopine surfaktanta s dodatkom kore ananasa iznosi 44,26 %. Na temelju rezultata ove studije može se zaključiti da korištenje kore ananasa pokazuje povoljan utjecaj na proces proizvodnje nafte.

Ključne riječi:
metoda povećanja iscrpka nafte (EOR), kora ananasa, međufazna napetost, surfaktant

Author's contribution

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