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Evaluation of the effectiveness of almond and castor seed oil demulsifiers for emulsion treatment

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ABSTRACT

Water production alongside crude oil almost always leads to emulsion formation, which poses serious challenges during production, transportation, and refining. These emulsions are often very stable and must be separated efficiently to ensure smooth operations and reduce costs. Chemical demulsification is the most common treatment method, but the use of synthetic chemicals raises environmental and economic concerns. This study investigates the efficiency of almond seed oil (AMSO) and castor seed oil (CSO) demulsifiers and compares them with the xylene demulsifier for crude oil emulsion treatment. Bottle tests were carried out using crude oil emulsions mixed with each demulsifier at ratios of 95:5, 90:10, 85:15, 80:20, and 75:25 (emulsion to demulsifier). The mixtures were stirred, agitated, and heated at different temperatures (28 °C, 40 °C, 60 °C, and 80 °C), and water separation was monitored over a 300-minute period at 30-minute intervals. The results showed that water separation improved with AMSO and CSO demulsifiers at higher dosages and longer separation times. Xylene remained the most effective demulsifier across all conditions, especially at elevated temperatures. However, CSO consistently outperformed AMSO, proving more responsive to both temperature and concentration. AMSO, while less effective, improved at higher dosages and at 80 °C. While xylene demulsifier remains the most efficient, CSO demulsifier shows real promise as a greener alternative. With further optimization, natural seed oils could provide a sustainable pathway for reducing dependence on synthetic demulsifiers in crude oil processing.

Contribution/Originality: This study contributes to the existing literature by introducing Almond and Castor Seed Oil as demulsifiers if optimized for Emulsion Treatment. It demonstrates that using higher concentrations of demulsifiers when subjected to higher temperature gives better water separation.

1. INTRODUCTION

Emulsions are mixtures of two immiscible liquids in which one liquid is dispersed in the other as droplets, and they occur widely in petroleum, food processing, pharmaceutical, and cosmetic industries [1]. In petroleum operations, the formation of water-in-oil (W/O) and oil-in-water (O/W) emulsions during crude oil production and processing creates significant technical challenges. These emulsions increase viscosity, cause corrosion, reduce throughput, and complicate downstream separation processes, leading to higher operational costs and environmental concerns [2, 3]. To address these problems, emulsions are treated through demulsification, a process of breaking them into their separate water and oil phases. Chemical demulsifiers are the most common solution, but many traditional types, such as xylene-based agents, are expensive, toxic, and environmentally persistent, thereby raising concerns over sustainability [4, 5].

The efficiency of demulsifiers depends on several factors, including temperature, concentration, and crude oil composition, as emulsions stabilized by asphaltenes, resins, and solids are often very difficult to treat [6, 7]. Past studies show that a one-size-fits-all approach does not guarantee optimal performance, as the complexity of crude emulsions requires tailored formulations that balance economic feasibility with environmental safety [8, 9]. These limitations underline the need for natural, biodegradable, and cost-effective alternatives that can reliably achieve water–oil separation under varied operational conditions. Plant-derived oils and agro-waste extracts present a promising option, with increasing attention directed towards their application in petroleum demulsification because of their renewability, availability, and lower environmental footprint [10, 11].

This study investigates the use of almond seed oil (AMSO) and castor seed oil (CSO), extracted from agro-waste, as natural demulsifiers for crude oil emulsion treatment in comparison with a conventional xylene demulsifier. The work is designed to formulate emulsions and demulsifiers using xylene, AMSO, and CSO, evaluate their effectiveness by measuring water separation at different temperatures, and determine the optimum demulsifier ratios and conditions for maximum performance. By combining environmental safety with cost-effectiveness, this research aims to reduce reliance on synthetic chemical demulsifiers while contributing to the development of sustainable solutions for crude oil emulsion treatment [12, 13].

2. LITERATURE REVIEW

The treatment of emulsions, particularly water-in-oil (W/O) emulsions, remains a central challenge in petroleum production, processing, and oil-water separation systems. Emulsions are two-phase systems comprising fine droplets of one liquid dispersed in another immiscible phase, stabilized by natural surfactants such as asphaltenes, resins, and fine solids inherent in crude oil, which form rigid interfacial films that prevent water droplet coalescence and hinder phase separation [14]. Emulsion formation is undeniable and unavoidable during the extraction and transportation of crude oil [15]. The formation of emulsion is influenced by emulsifying agents at the oil-water interfaces, the water phase, and pressure drop [5, 16]. Numerous approaches have been used for the treatment of emulsions and are enhanced by increasing temperature, centrifugation, electrical method, long resonance time, and chemical treatment (Demulsifiers) [17, 18]. Efficient demulsification is critical to reduce corrosion, pumping costs, and meet market specifications for crude oil quality (Water limits) [19].

Demulsifiers are chemicals that destabilize emulsions by disrupting the interfacial film and promoting droplet coalescence and phase separation. Chemical demulsification and molecular optimization of natural oil demulsifiers have been identified as the cheapest, most convenient, and most efficient in the separation of water-in-oil emulsions [20, 21]. Traditional chemical demulsifiers include synthetic surfactants, polymers, and copolymers that adsorb at the oil-water interface, reduce interfacial tension, and displace crude emulsifiers [22]. However, many of these conventional agents have environmental and economic drawbacks, motivating research into biodegradable, eco-friendly alternatives such as natural oils and seed-derived demulsifiers [23].

Natural almond oil likewise contains a mix of long-chain triglycerides that can participate in emulsion destabilization, but its specific application as a demulsifier has been comparatively less investigated in literature compared with castor-derived systems Akinyemi, et al. [24]. Hajivand and Vaziri [25] synthesized castor oil maleate (MACO) molecules with varied degrees of maleic anhydride incorporation and demonstrated interfacial activity that yielded up to 90 % water resolution from water-in-crude oil emulsions at optimal structures. Similarly, Elsharaky et al. [26] showed that castor oil-based additives with tailored structures could achieve 90 % demulsification efficiency under standardized bottle test conditions and interfacial tension evaluations, highlighting the significance of molecular diffusivity and oil-water interface interactions.

Several natural oils have been used for demulsifier formulation; however, there is a gap regarding the direct comparison of almond and castor oil demulsifiers under standardized testing conditions. While castor oil derivatives have been chemically modified and studied with measurable efficiencies, literature on almond oil's demulsifier performance is less comprehensive, often limited to case studies without deep mechanistic examinations [27]. While many studies on natural demulsifiers confirm biodegradability and environmental benefits, challenges such as longer demulsification times and higher required dosages have been noted. Studies of other plant oils (sesame, soursop, jatropha) demonstrate that seed oil-based demulsifiers can indeed achieve notable separation efficiencies, particularly when formulated with appropriate surfactants or polymeric additives. This work investigates the efficiency of Almond and Castor seed oil demulsifiers at different concentrations and temperatures for emulsion treatment.

3. MATERIALS AND METHODS

Crude oil emulsion, almond seed oil (AMSO), castor seed oil (CSO), and xylene were the main materials used. Additives include camphor powder, cassava starch, paraffin wax, diesel, liquid soap, and sodium phosphate (NaH_2PO_4). Standard laboratory apparatus, such as a weighing balance, heating mantle, thermometer, measuring cylinders, and mixers, was employed.

The crude oil was characterized to determine its density, viscosity, specific gravity, and API gravity.

A stable water-in-oil emulsion was prepared by blending crude oil with water and sodium phosphate. The conventional xylene-based demulsifier was formulated by mixing xylene, diesel, camphor, paraffin wax, cassava starch, and liquid soap, while local demulsifiers were prepared by combining either almond seed oil (AMSO) or castor seed oil (CSO) with camphor powder, cassava starch, and liquid soap at 40°C.

The demulsification performance was assessed using the standard bottle test method, a widely accepted laboratory technique for evaluating demulsifiers [28]. For each test, 95 mL of the prepared crude oil emulsion was placed in a test bottle, and 5 mL of demulsifier was added. The mixtures were subjected to different concentration ratios (95:5, 90:10, 85:15, 80:20, and 75:25) and heated at temperatures of 28°C, 40°C, 60°C, and 80°C. Water separation was monitored at intervals up to 300 minutes, and the results for AMSO and CSO were compared with the conventional xylene demulsifier. The sample identification and emulsion-to-demulsifier ratio are shown in Table 1.

Table 1. Experimental design for demulsifier evaluation.

Sample	Content	Ratio (Emulsion: Demulsifier)
D1–D5	Emulsion: XYL demulsifier	95:5, 90:10, 85:15, 80:20, 75:25
E1–E5	Emulsion: AMSO demulsifier	95:5, 90:10, 85:15, 80:20, 75:25
F1–F5	Emulsion: CSO demulsifier	95:5, 90:10, 85:15, 80:20, 75:25

This design allowed systematic evaluation of demulsifier performance under varying concentrations and thermal conditions.

4. RESULTS AND DISCUSSION

4.1. Crude Oil Properties

The crude sample density, specific gravity, API gravity and viscosity were determined and presented in Table 2.

Table 2. Crude oil properties.

Properties	Value
Density (kg/m³)	0.9896kg/m³
Specific Gravity	0.9896
API Gravity	26.77⁰
Viscosity (cp)	14.14 cp

4.2. Water Separation Using Xylene Demulsifier at Different Temperatures

Figure 1 illustrates the performance of xylene at room temperature (28 °C). At room temperature, there was very little water separation. The emulsion remained quite stable, showing that without heat, xylene on its own struggled to break through the stabilizing layers in the crude. This highlights that in ambient conditions, the crude was too viscous for the demulsifier to act effectively.

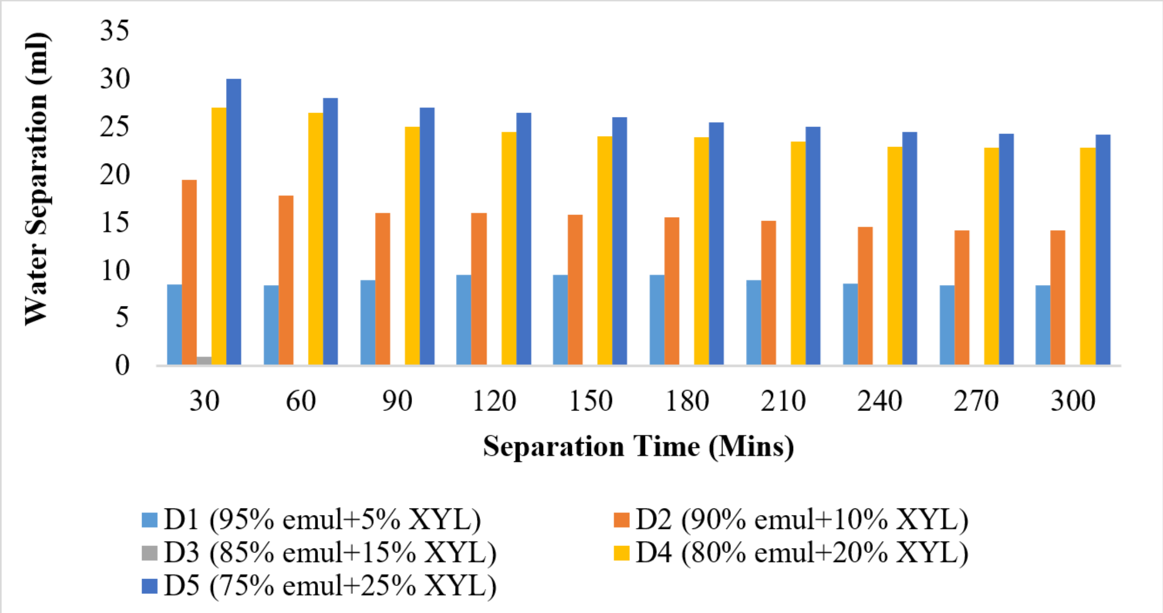

Figure 1. Water separation at different times from $D_1 - D_5$ at Room Temperature (28 °C).

The water separation at different time intervals for the xylene demulsifier at 40 °C is presented in Figure 2. The extra heat above the room temperature reduced the viscosity of the crude, allowing water droplets to move more freely and giving xylene a better chance to interact with and weaken the interfacial films. Even though performance improved compared to room temperature, the separation at this stage was still only moderate.

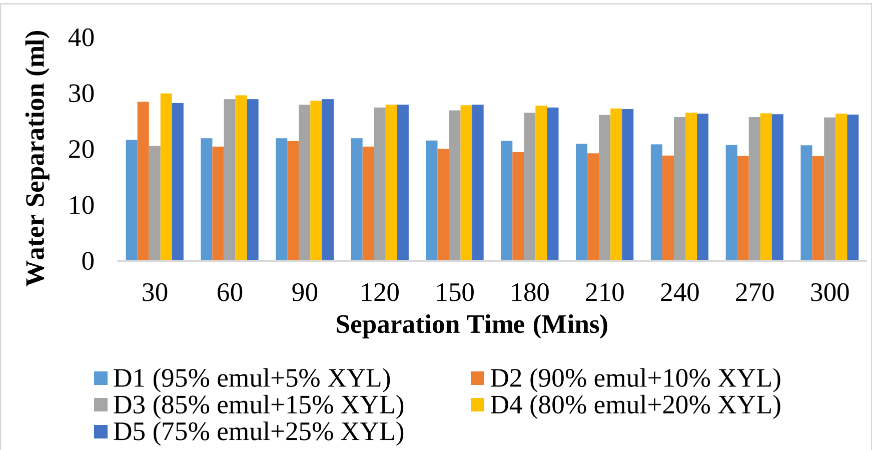

Figure 2. Water separation at different times from $D_1 - D_5$ at 40⁰C.

The water separation at different time intervals at 60 °C for the xylene demulsifier is presented in Figure 3. With more heat, the interfacial films around the water droplets lost some of their strength, allowing xylene to act more efficiently. Water separation increased clearly, confirming that temperature plays a strong role in helping the demulsifier perform.

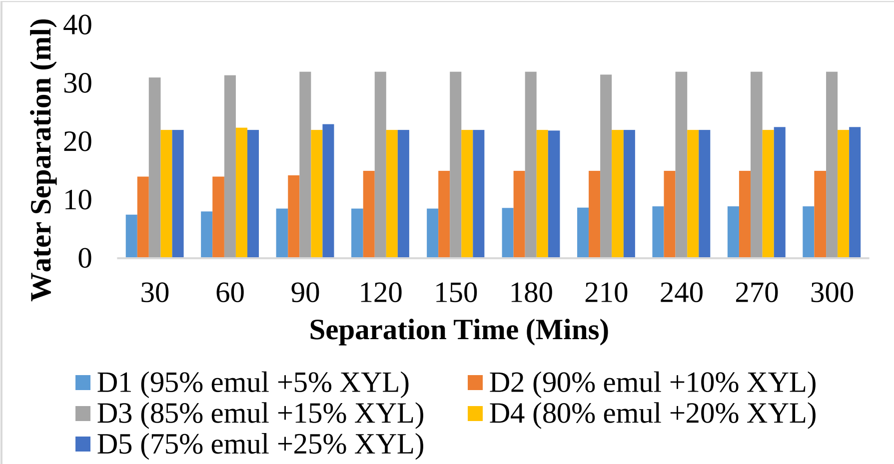

Figure 3. Water separation at different times from $D_1 - D_5$ at 60°C.

The xylene demulsifier level of water separation at 80 °C is shown in Figure 4. The combined effect of reduced viscosity and stronger chemical action allowed the emulsion to break more easily, producing the highest water recovery. However, after a point, the rate of improvement flattened, suggesting that pushing the temperature even higher would not add much benefit.

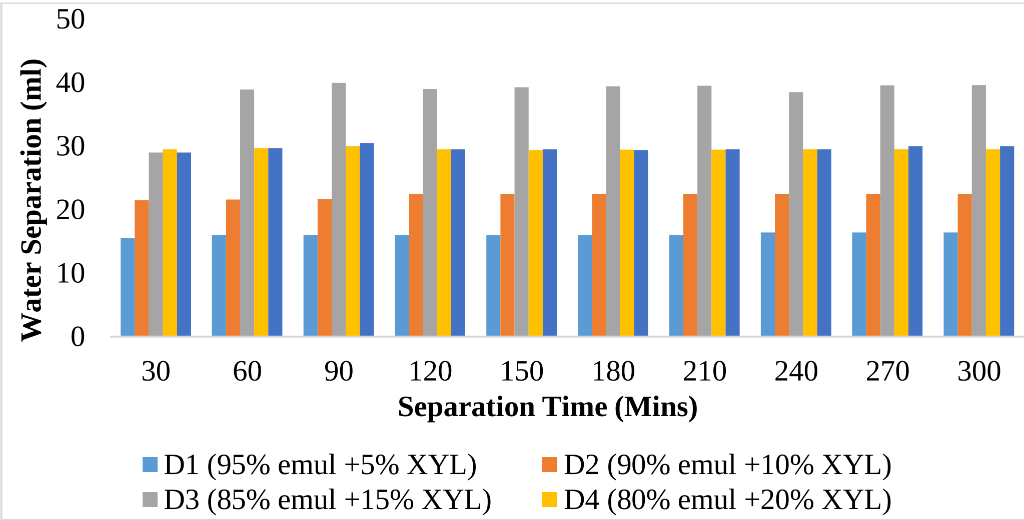

Figure 4. Water separation at different times from $D_1 - D_5$ at 80°C.

The xylene showed very poor efficiency at room temperature but became progressively more effective as the temperature increased, with the best results obtained at 80 °C. This demonstrates that xylene is highly temperature-dependent, and applying sufficient heat is key to unlocking its full demulsification potential.

4.3. Water Separation Using Almond Seed Oil (AMSO) Demulsifier at Different Temperatures

Almond seed oil (AMSO) demulsifier showed that its performance depends strongly on both the temperature and the concentration.

At room temperature (28 °C), AMSO had almost no effect on the emulsion, as presented in Figure 5. Even when higher concentrations were applied, the crude remained stable and very little water separated. This shows that the crude was viscous, and the stabilizing layers around the water droplets were too strong for the natural oil to break through.

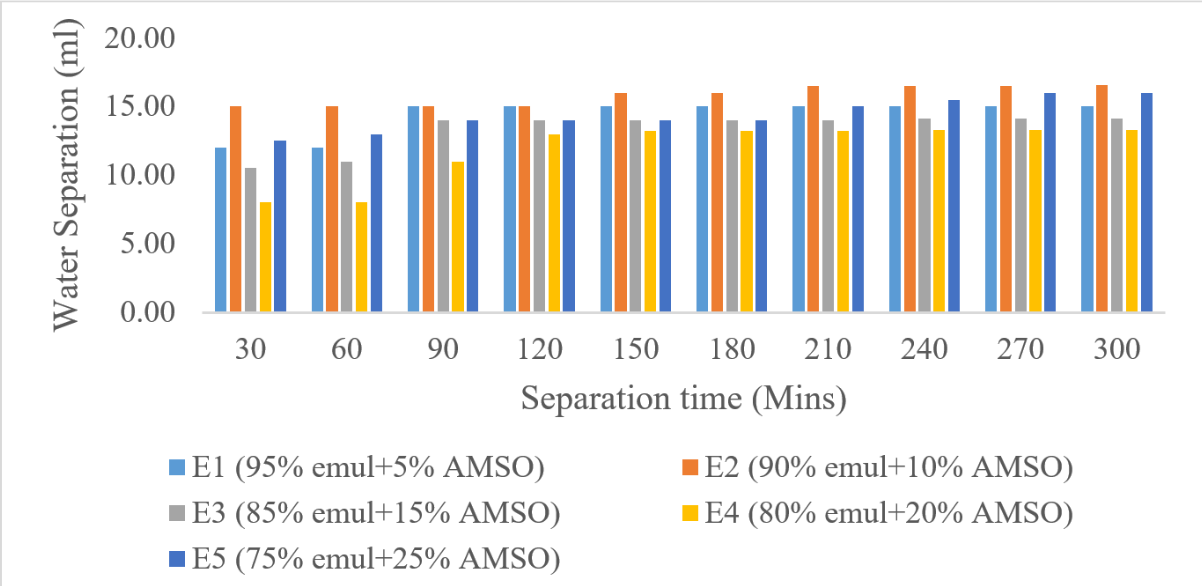

Figure 5. Water separation at different times from $E_1 – E_5$ at Room Temperature (28^{o}C).

Figure 6 shows the water separation level at 40 °C for different dosages of the AMSO demulsifier. The added heat made the crude less viscous, and increasing the AMSO concentration allowed slightly more water to separate. Still, the effect was limited, showing that mild heating and concentration alone were not enough to make a big difference.

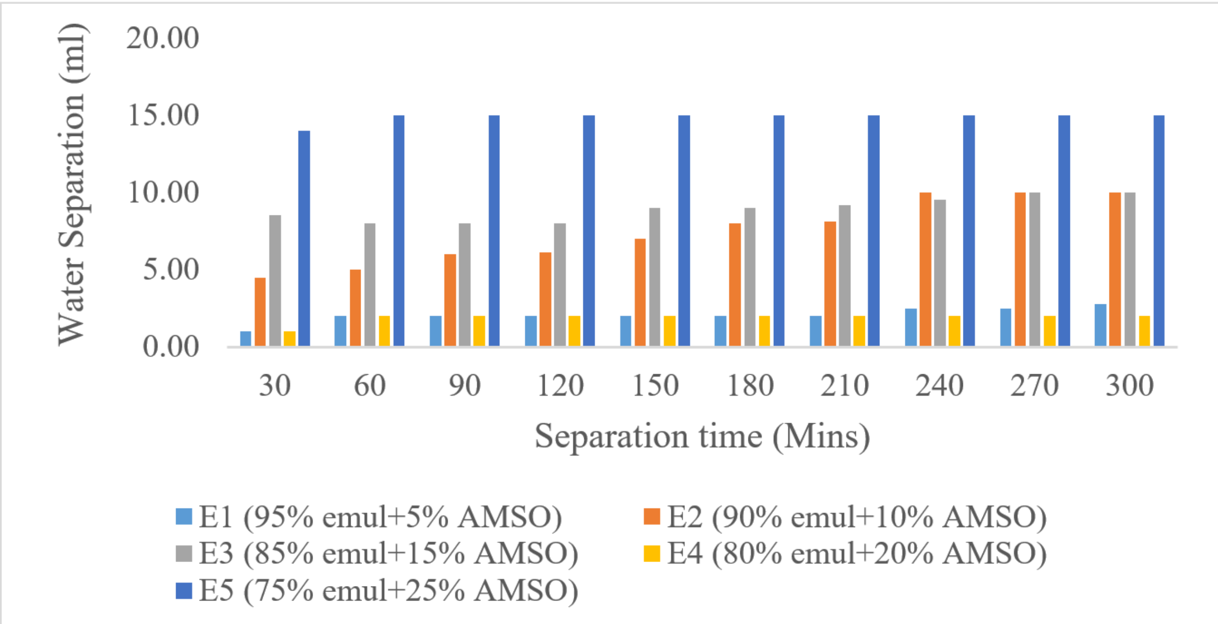

Figure 6. Water separation at different times from $E_1 – E_5$ at 40^{o}C.

At 60 °C, as presented in Figure 7, AMSO began to perform much better. Increase in temperature and concentration of the AMSO reduces the crude's viscosity further, making it easier for AMSO molecules to interact with the droplets. At higher ratios like 80:20 and 75:25, noticeably more water separation was recorded compared to the lower doses, showing more impact of the concentration.

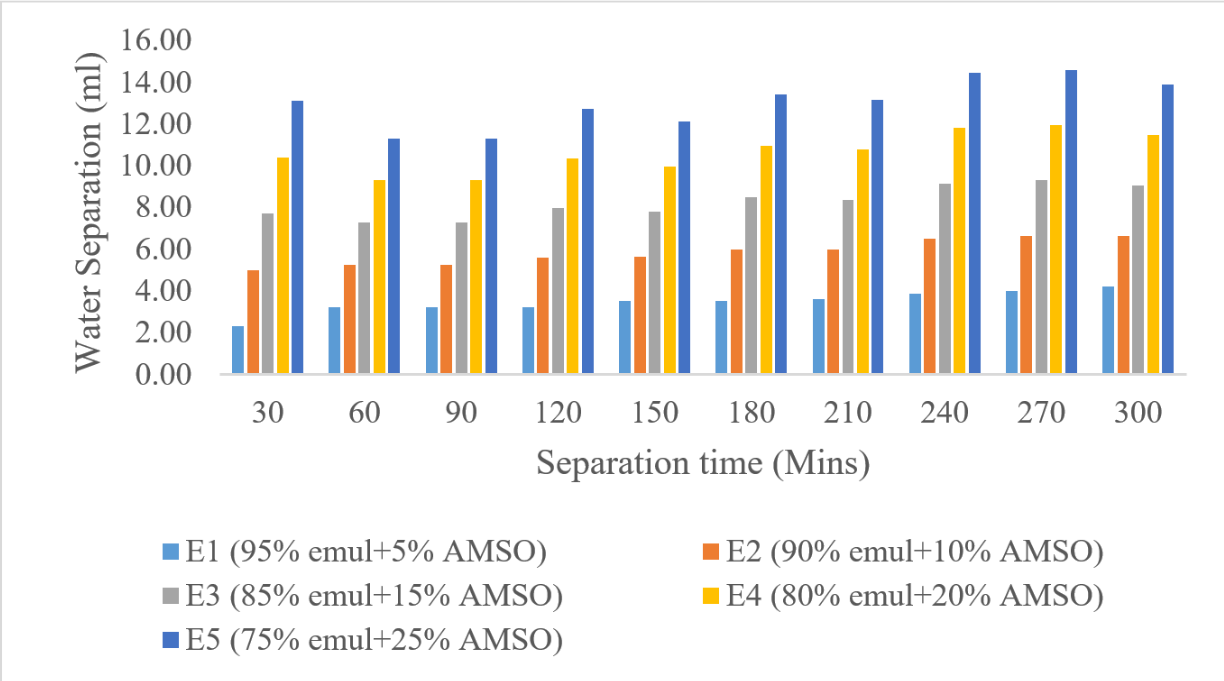

Figure 7. Water separation at different times from $E_1 - E_5$ at 60^{o}C.

The best performance of the AMSO demulsifier was at 80 °C, as shown in Figure 8. **T**he emulsion broke more easily, and increasing the AMSO concentration gave the highest levels of water separation. The combined effect of heat, which weakened the protective films, and a higher dose of AMSO, which supplied more active compounds, allowed much better droplet coalescence. Even so, AMSO still did not match the efficiency of xylene under the same conditions.

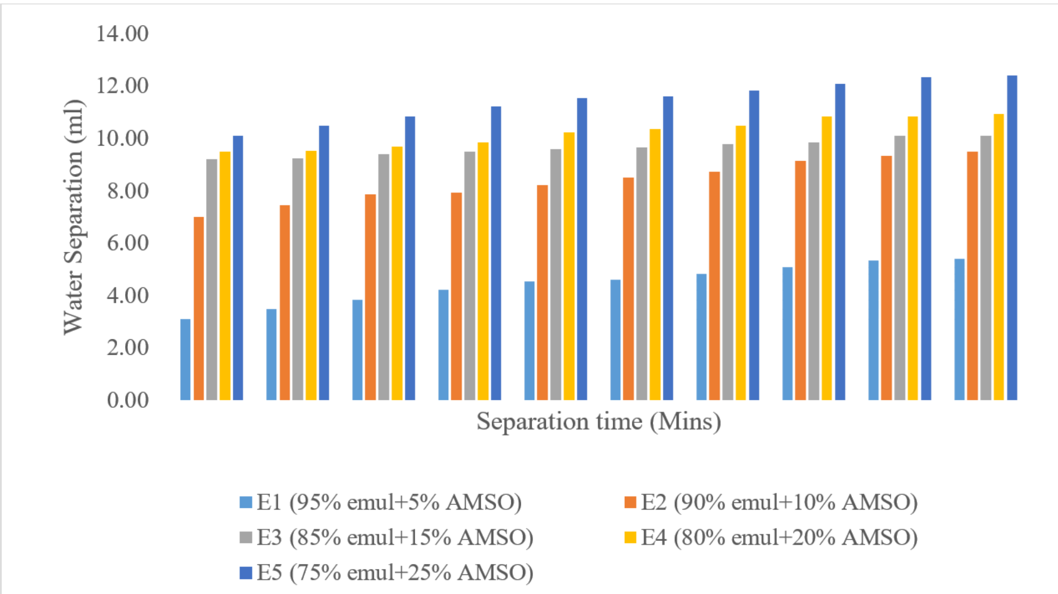

Figure 8. Water separation at different times from $E_1 - E_5$ at 80^{o}C.

AMSO was weak at room temperature, improved slightly with moderate heating, and became effective only at higher temperatures, where increased concentration also played a key role. This shows that almond seed oil is both temperature-sensitive and dosage-dependent, needing enough heat and sufficient concentration before it can act as a reliable natural demulsifier.

4.4. Water Separation Using Castor Seed Oil (CSO) Demulsifier at Different Temperatures

The performance of castor seed oil (CSO) demulsifier showed a clear dependence on both temperature and concentration, and compared to almond seed oil, CSO generally performed a little better.

At room temperature (28 °C), as presented in Figure 9, CSO hardly made any difference. No matter the concentration, the emulsion remained intact, and there was very little water separation. The crude was simply too viscous, and the stabilizing films around the droplets were too strong for CSO to act at this stage.

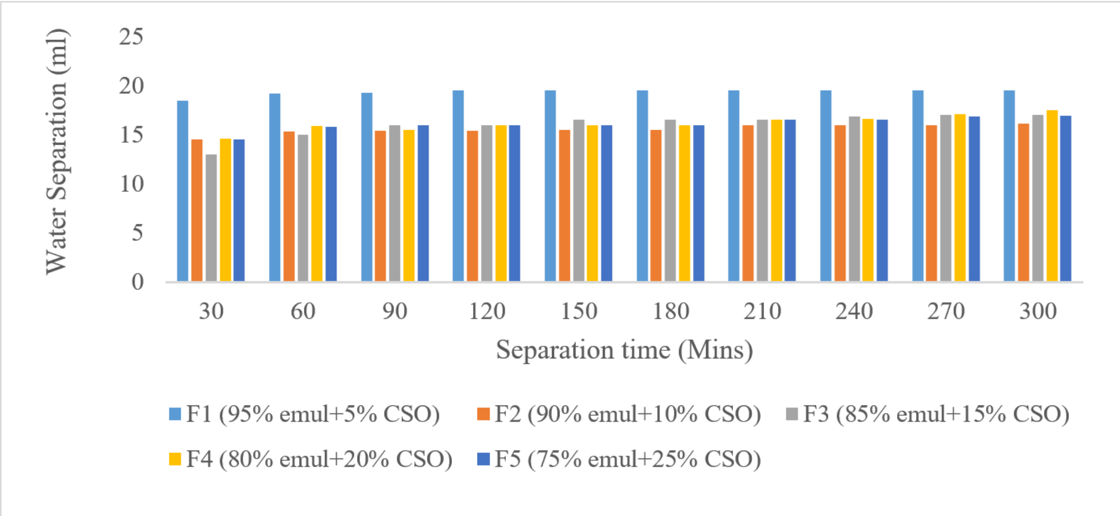

Figure 9. Water separation at different times from $F_1 – F_5$ at room temperature (28^0C).

At 40 °C, as shown in Figure 10, there was a small but noticeable improvement. The slight heating helped reduce the crude's viscosity, giving CSO more room to act. Higher concentrations produced slightly better separation than lower ones, but the effect was still weak. This suggests that CSO, like other natural demulsifiers, needs more heat before it can really start breaking.

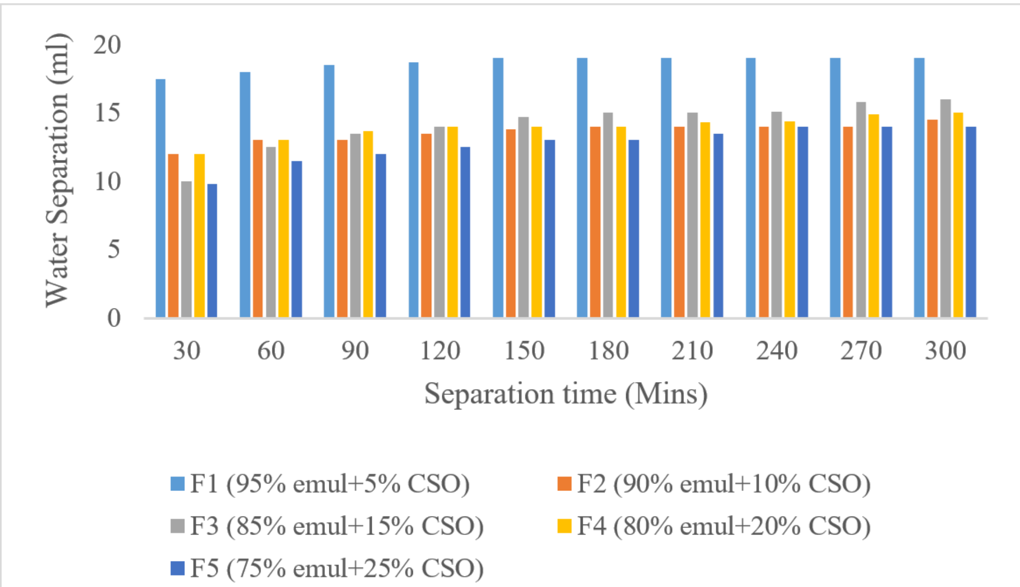

Figure 10. Water separation at different times from $F_1 – F_5$ at 40^0C.

When the temperature was raised to 60 °C, as presented in Figure 11, CSO began to show much water separation. The higher heat weakened the interfacial films and allowed water droplets to move more freely. At this point, concentration made a big difference: higher ratios (such as 80:20 and 75:25) clearly separated more water than the lower doses. This shows that both temperature and dosage work together to bring out the potential of CSO.

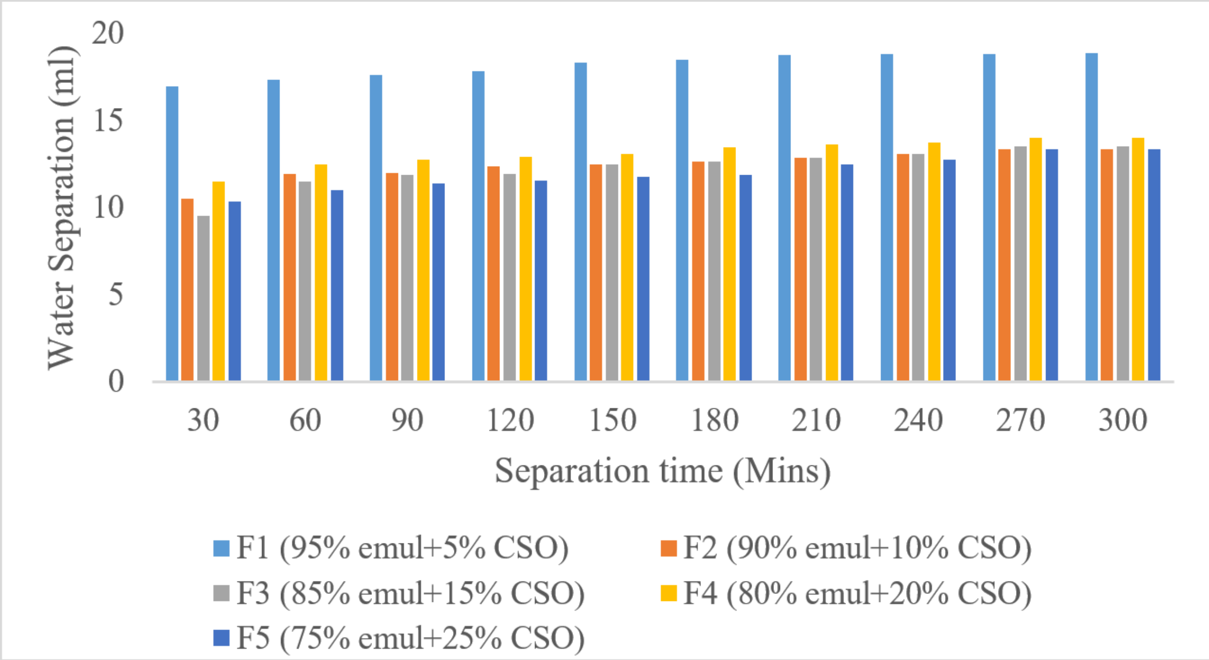

Figure 11. Water separation at different times from $F_1 - F_5$ at 60°C.

At 80 °C, as shown in Figure 12, CSO achieved its best performance. The crude was now much less viscous, and the demulsifier attacked the stabilizing films effectively. Water Separation was highest at this stage, especially at higher concentrations. While CSO did not perform as strongly as xylene, it gave better results than almond seed oil under the same conditions, making it a more promising natural alternative.

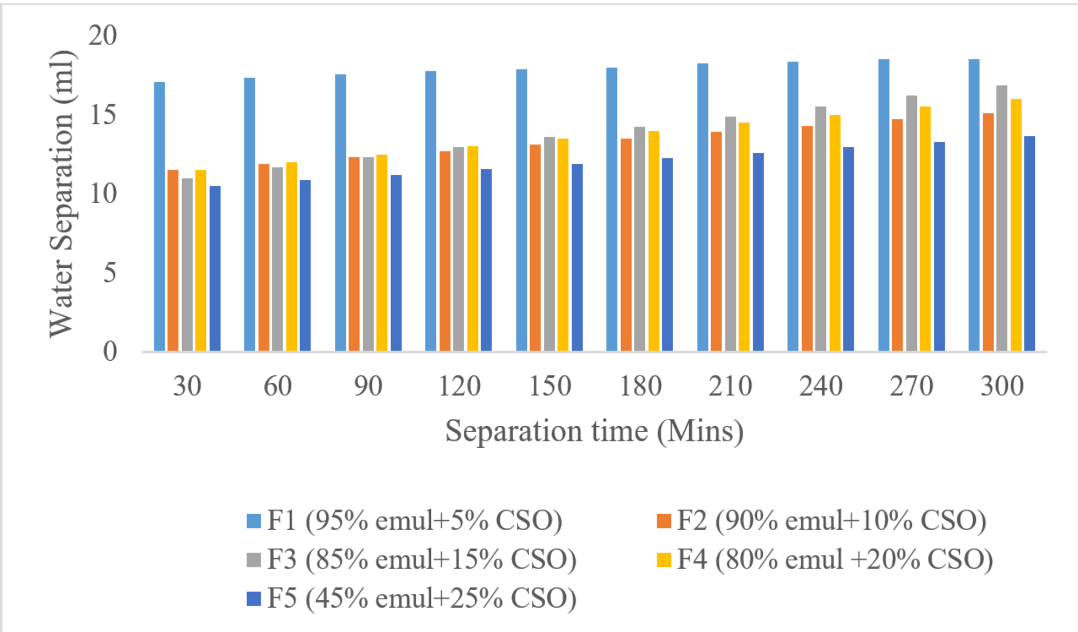

Figure 12. Water separation at different times from $F_1 - F_5$ at 80°C.

The CSO was almost ineffective at room temperature, started to improve slightly at 40 °C, became clearly effective at 60 °C, and worked best at 80 °C, especially when applied in higher concentrations. This shows that CSO, like AMSO, is highly temperature and concentration-sensitive, but it stands out as the more effective of the two natural oils tested.

4.5. Water Separation for Different Demulsifier Ratios at Room Temperature (28 °C)

At room temperature (28 °C), the crude oil emulsions remained very stable, and none of the demulsifiers xylene, almond seed oil (AMSO), or castor seed oil (CSO) showed strong efficiency. Figures 1, 5, and 9 illustrate that across all concentration ratios (95:5 to 75:25), water separation was minimal. The stability of the emulsion at this temperature can be explained by the relatively high viscosity of the crude, which prevented the dispersed water droplets from moving freely and coalescing.

Xylene gave slightly higher separation than the natural oils, but the values were still too small to be of practical significance. AMSO performed the weakest, showing almost no separation at any ratio, while CSO did marginally better but was still far below the performance required for effective demulsification. Increasing the dosage of either natural oil from 5% to 25% made almost no difference at this stage. These results suggest that without thermal activation, none of the demulsifiers could penetrate the stabilizing films formed by asphaltenes, resins, and solids present in the crude oil. At ambient conditions, concentration had little effect, and all three demulsifiers were practically inactive.

4.6. Water Separation for Different Demulsifier Ratios at 40 °C

When the temperature increased to 40 °C, a small but noticeable improvement was observed across all demulsifiers. The heating reduced crude viscosity slightly, allowing water droplets more mobility and giving demulsifier molecules better access to the interface. As shown in Figures 2, 6, and 10, xylene responded the best to this change, producing more separation than the natural oils. Although the improvement was not dramatic, the difference compared to room temperature confirmed that temperature is an important factor in activating demulsifier action.

Among the natural oils, CSO outperformed AMSO at most ratios, particularly at higher concentrations of 80:20 and 75:25, where water separation improved noticeably. AMSO, however, remained weak, with only minor changes even as the concentration increased. The results suggest that natural demulsifiers are less sensitive to moderate temperature increases compared to xylene. At this point, the role of concentration was still limited, but it became clear that higher dosages combined with heat could begin to enhance separation.

4.7. Water Separation for Different Demulsifier Ratios at 60 °C

At 60 °C, the impact of both temperature and concentration became more significant. Xylene achieved a much higher degree of water separation, confirming its effectiveness under heated conditions. The crude's viscosity was reduced enough for xylene molecules to disrupt the interfacial films more efficiently, allowing water droplets to coalesce and settle.

The natural oils also showed stronger results at this stage, with CSO clearly outperforming AMSO. At higher concentrations (80:20 and 75:25 ratios), CSO produced good levels of separation, indicating that its active compounds were more effective when supported by higher dosages and heat. AMSO, though improved compared to earlier conditions, still lagged. The difference between CSO and AMSO became more pronounced at this temperature, with CSO showing real potential as a viable natural demulsifier.

This stage demonstrated that both heat and concentration are required for natural oils to act effectively. Lower concentrations did not provide enough active material, but higher doses in combination with elevated temperature allowed the oils to interact more strongly with the emulsion.

4.8. Water Separation for Different Demulsifier Ratios at 80 °C

At 80 °C, all three demulsifiers achieved their maximum performance. The high temperature significantly lowered crude oil viscosity, which increased droplet mobility and weakened protective interfacial films. Xylene recorded the highest water separation overall, confirming its superiority as a synthetic chemical demulsifier. Across all concentration ratios, xylene was consistently more effective than both AMSO and CSO.

The natural oils also recorded their best results at this temperature. CSO once again performed better than AMSO, particularly at higher dosages, where water recovery was noticeably higher. AMSO, although improved compared to earlier stages, remained the weakest performer of the three. These results confirm that while natural oils can achieve some degree of demulsification under high-temperature conditions, they still fall short of matching the efficiency of xylene.

The effect of concentration was clearest at 80 °C. At lower dosages, separation was moderate, but as the demulsifier concentration increased to 20% and 25%, water recovery improved significantly for both natural oils. This shows that the combination of high temperature and sufficient dosage is essential for natural demulsifiers to perform effectively.

4.9. Effects of Concentration of Demulsifiers at Room Temperature (28°C)

Figure 13 shows the performances in the ratio of different demulsifiers (Xylene, AMSO, and CSO) in 300 minutes at room temperature conditions. The results show that xylene has optimal water separation at the D_3 ratio in all the separation times. Also, CSO demulsifier increases by 5% than AMSO. Therefore, xylene optimally separates water more than AMSO and CSO, with an optimal water separation of 30%.

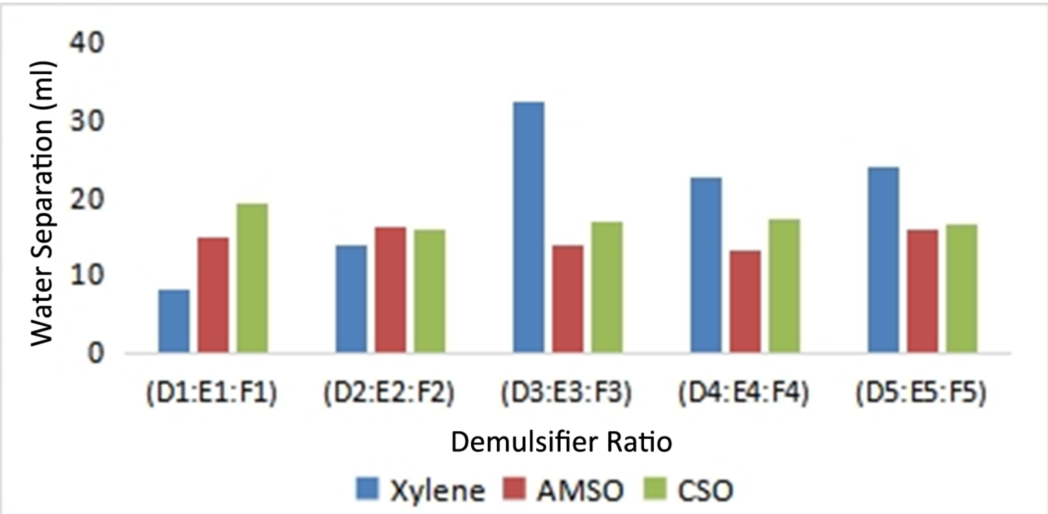

Figure 13. Water separation to different demulsifier ratios at room temperature under 300 minutes of separation.

4.10. Effects of Concentration of Demulsifiers at 40°C

Figure 14 shows the performances in the ratio of different demulsifiers (Xylene, AMSO, and CSO) in 300 minutes at 40°C temperature condition. The result shows the effectiveness of xylene demulsifier in recovering optimal water separation as the demulsifier ratio increases. Also, there was a drastic decrease in the separation level of CSO demulsifier as the concentration increased (the higher the concentration level of CSO, the lower the volume of water separation). Moreso, CSO demulsifier becomes unstable as its concentration increases.

Generally, xylene demulsifier is optimal in water separation as the concentration increases more than CSO and AMSO, with an optimal water separation of 25%.

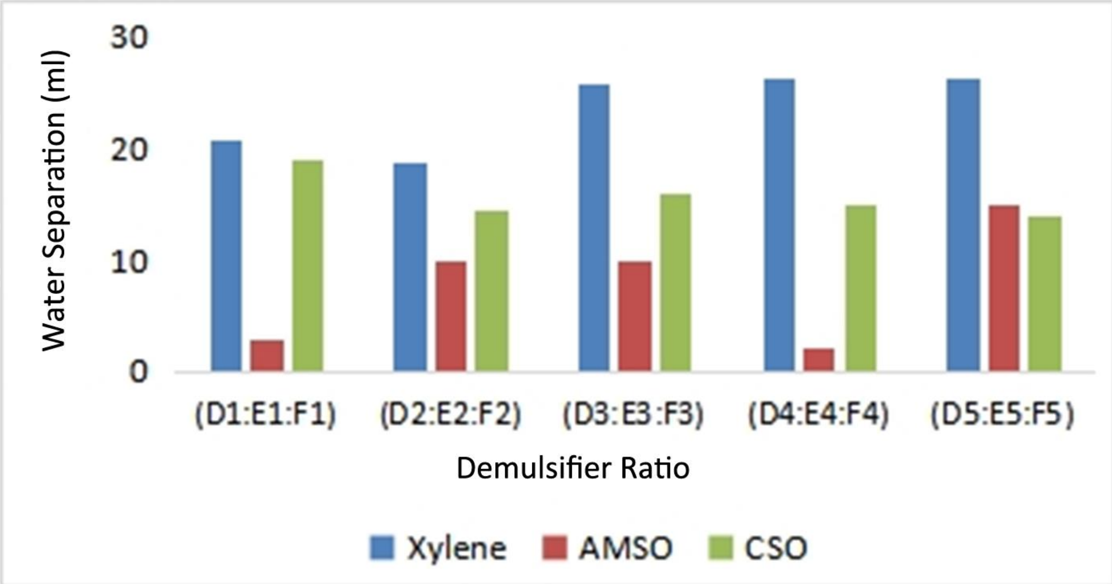

Figure 14. Water separation to different demulsifier ratios at 40⁰C under 300mins of separation.

4.11. Effects of Concentration of Demulsifiers at 60⁰C

The performances in the ratio of different demulsifiers (Xylene, AMSO, and CSO) in 300 minutes at 60⁰C temperature condition are presented in Figure 15. The result shows the effectiveness of xylene demulsifier in recovering optimal water separation at the D_3 ratio. There was a slight decrease in the separation level of CSO demulsifier as the concentration increased (the higher the concentration level of CSO, the lower the volume of water separation). Moreso, the AMSO demulsifier increases slowly as the concentration increases. Therefore, the xylene demulsifier was optimal in water separation only at D_3 concentration.

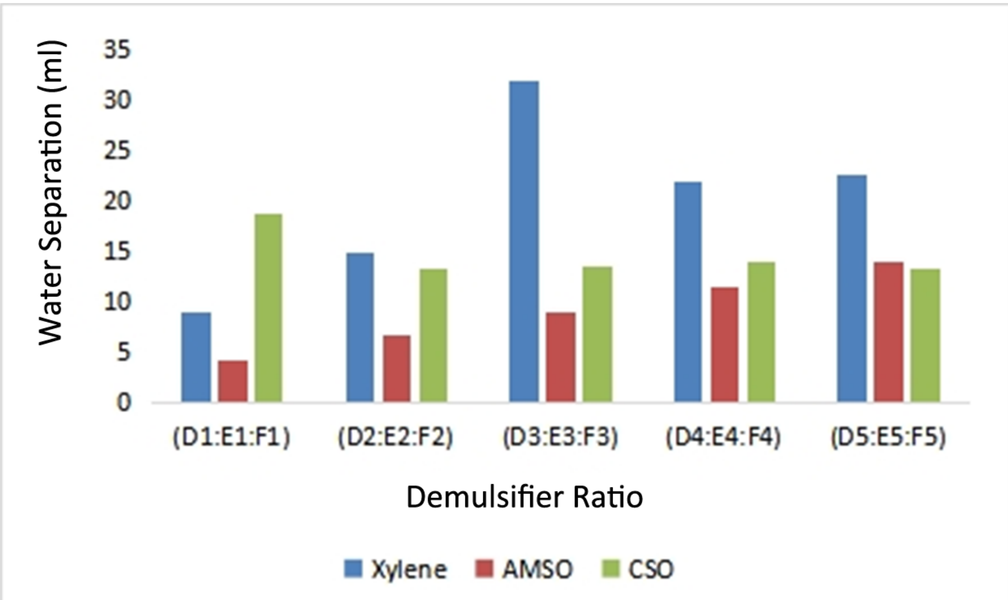

Figure 15. Water separation to different demulsifier ratios at 60⁰C under 300 minutes of separation.

4.12. Effects of Concentration of Demulsifiers at 80⁰C

Figure 16 shows the performances in the ratio of different demulsifiers (Xylene, AMSO, and CSO) in 300 minutes at 80⁰C temperature condition. The result also shows the effectiveness of xylene demulsifier with optimal water separation at D_3 concentration, but decreases slowly as the concentration increases. Also, there is a drastic decrease in the separation level of AMSO and CSO demulsifiers as the temperature, concentration, and separation time increase.

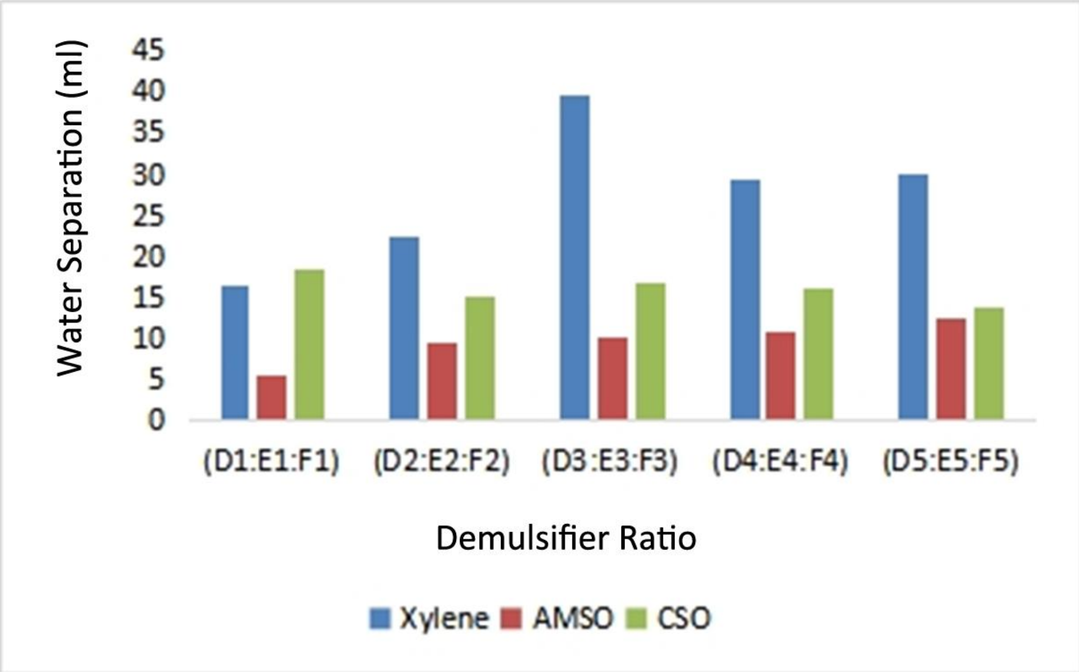

Figure 16. Water separation to different demulsifier ratios at 80^{0}C under 300 minutes of separation.

5. CONCLUSION

This study evaluated the performance of almond seed oil (AMSO) and castor seed oil (CSO) demulsifiers in comparison with a conventional xylene demulsifier for the treatment of water-in-oil emulsions under different temperature conditions and demulsifier ratios, using the bottle test method. The following conclusions were drawn:

i. Xylene demulsifier produced the highest water separation across all tests, with efficiency strongly enhanced at elevated temperatures, confirming its superiority as a synthetic chemical demulsifier.

ii. Castor seed oil (CSO) demulsifier showed better performance than almond seed oil (AMSO) and was clearly temperature and concentration-dependent, achieving its best separation at higher ratios and temperature.

iii. Almond seed oil (AMSO) demulsifier has the lowest water separation, with weak performance at low and moderate temperatures, and though improved at higher concentrations and at the highest temperature, it remained less effective than both CSO and xylene.

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Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.

REFERENCES

[1] F. S. Manning, R. E. Thompson, and J. Turk, *Oilfield processing of petroleum: Crude oil.* United States: PennWell Books, 2019.

[2] S. Kokal and O. Al-Dokhi, "Case studies in demulsifier evaluation and development," *SPE Production & Operations*, vol. 22, no. 1, pp. 5–13, 2007.

[3] D. Yang, H. Jia, and Z. Xu, "Effects of demulsifiers on separation of water-in-oil emulsions," *Energy & Fuels*, vol. 27, no. 9, pp. 5440–5448, 2013.

[4] J. Neff, K. Lee, and E. M. DeBlois, *Produced water: Overview of composition, fates, and effects. In K. Lee & J. Neff (Eds.), Produced water: Environmental risks and advances in mitigation technologies*. New York: Springer, 2011.

[5] R. Zolfaghari, A. Fakhru'l-Razi, L. C. Abdullah, S. S. E. H. Elnashaie, and A. Pendashteh, "Demulsification techniques of water-in-oil and oil-in-water emulsions in petroleum industry," *Separation and Purification Technology*, vol. 170, pp. 377-407, 2016. https://doi.org/10.1016/j.seppur.2016.06.026

[6] B. P. Binks, *Modern aspects of emulsion science*. United Kingdom: Royal Society of Chemistry, 1998.

[7] O. Rocha, Y. Lu, and J. Xu, "Influence of chemical additives on crude oil demulsification," *Journal of Petroleum Science and Engineering*, vol. 157, pp. 836–844, 2017.

[8] Z. Wu, C. Dai, M. Li, and H. Sun, "Scale-up challenges of demulsifier performance from lab to field," *Fuel*, vol. 300, p. 120973, 2021.

[9] M. Li, C. Ye, H. Sun, and Z. Wu, "Emulsion stability and demulsification: A review on the role of asphaltenes and resins," *Fuel*, vol. 245, pp. 45–57, 2019.

[10] N. H. Abdurahman, Y. M. Rosli, N. H. Azhari, and R. M. Yunus, "Demulsification of water-in-crude oil emulsion via microwave heating technology," *Journal of Applied Sciences*, vol. 11, no. 16, pp. 2948–2953, 2011.

[11] E. Ramirez-Jaramillo, A. Rodríguez, and J. Giraldo, "Application of polyamine demulsifiers in heavy crude oil emulsions," *Energy & Fuels*, vol. 25, no. 1, pp. 49–55, 2011.

[12] T. Mheta and T. Sharma, "Emulsion treatment in crude oil production: An overview of recent developments," *Petroleum Research*, vol. 5, no. 4, pp. 321–330, 2020.

[13] M. Raza and K. Lee, "Advances in crude oil demulsification: A review," *Fuel*, vol. 290, p. 120012, 2012.

[14] M. Mohyaldinn, A. M. Hassan, and M. A. Ayoub, *Application of emulsions and microemulsions in enhanced oil recovery and well stimulation. In A. M. El-Sayed (Ed.), Emulsions*. London, UK: IntechOpen, 2018.

[15] J. Sjöblom, *Encyclopedic handbook of emulsion technology*. New York: CRC Press, 2001.

[16] J. J. Sheng, *Modern chemical enhanced oil recovery: Theory and practice*. Oxford, England: Gulf Professional Publishing, 2010.

[17] M. Nikkhah, T. Tohidian, M. R. Rahimpour, and A. Jahanmiri, "Efficient demulsification of water-in-oil emulsion by a novel nano-titania modified chemical demulsifier," *Chemical Engineering Research and Design*, vol. 94, pp. 164-172, 2015. https://doi.org/10.1016/j.cherd.2014.07.021

[18] A. H. Behroozi, N. Kasiri, and T. Mohammadi, "Multi-phenomenal macroscopic investigation of cross-flow membrane flux in microfiltration of oil-in-water emulsion, experimental & computational," *Journal of Water Process Engineering*, vol. 32, p. 100962, 2019. https://doi.org/10.1016/j.jwpe.2019.100962

[19] S. A. Raya, I. Mohd Saaid, A. Abbas Ahmed, and A. Abubakar Umar, "A critical review of development and demulsification mechanisms of crude oil emulsion in the petroleum industry," *Journal of Petroleum Exploration and Production Technology*, vol. 10, no. 4, pp. 1711-1728, 2020. https://doi.org/10.1007/s13202-020-00830-7

[20] R. S. Alves *et al.*, "Molecular optimization of castor oil maleate as demulsifier for water-in-crude oil emulsions," *Fuel*, vol. 322, p. 124204, 2022. https://doi.org/10.1016/j.fuel.2022.124204

[21] H. N. Abdurahman and M. Nuraini, "Chemical destabilization on water in oil emulsion," *World Academy of Science and Technology*, vol. 38, pp. 700-703, 2010.

[22] F. O. Adebanjo and O. C. Aduroja, "Development of local demulsifier for water-in-oil emulsion treatment," *International Journal of Sciences: Basic and Applied Research*, vol. 24, pp. 301-320, 2015.

[23] Y. Dhandhi, T. K. Naiya, and C. Guria, "Development of high-performance biodegradable and non-toxic demulsifier for dehydration of field crude oil emulsion: Statistical design and process optimization," *Geoenergy Science and Engineering*, vol. 234, p. 212677, 2024. https://doi.org/10.1016/j.geoen.2024.212677

[24] P. O. Akinyemi, D. J. Udonne, and K. F. K. Oyedeko, "Demulsification of crude oil emulsion using blend of triethanolamine and propan-2-ol," *Journal of the Nigerian Society of Chemical Engineers*, vol. 30, no. 1, pp. 41–44, 2015.

[25] P. Hajivand and A. Vaziri, "Optimization of demulsifier formulation for separation of water from crude oil emulsions," *Brazilian Journal of Chemical Engineering*, vol. 32, no. 1, pp. 107-118, 2015. https://doi.org/10.1590/0104-6632.20150321s00002755

[26] E. A. Elsharaky, A. S. El-Tabei, and A. E. El-Tabey, "The influence of newly synthesized demulsifiers on the interfacial rheological properties of a naturally occurring water/oil emulsion," *ACS Omega*, vol. 7, no. 36, pp. 32471-32480, 2022. https://doi.org/10.1021/acsomega.2c03958

[27] O. P. Akinyemi, J. O. Benjamin, and F. O. Banjoko, "Investigation of coconut oil as green demulsifier in crude oil emulsions," *Journal of Scientific and Engineering Research*, vol. 10, no. 4, pp. 47–53, 2023.

[28] B. B. Kinate, E. I. Okon, and I. N. Inuaeyen, "Experimental investigation of the suitability of Allanblackia seed oil and Moringa seed oil demulsifiers for emulsion treatment," presented at the SPE Nigeria Annual International Conference and Exhibition, 2025.