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Synthesis of advanced Biopolymers through Chemo-selective Approach for Enhanced Oil Recovery from Non-producing Reservoirs

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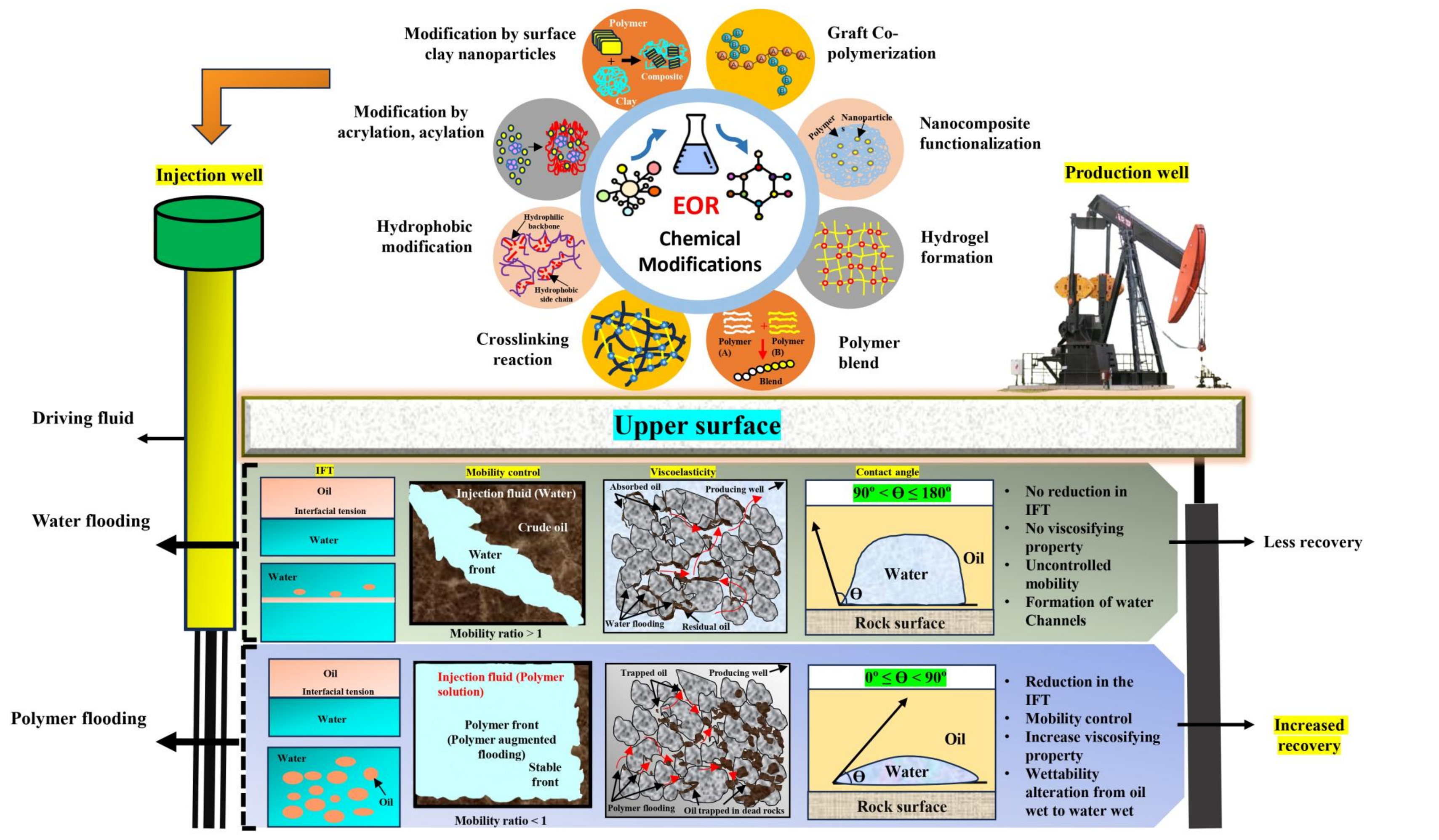
INTRODUCTION & AIM

- The Problem: Conventional oil recovery methods leave 50-70% of oil trapped in reservoirs due to high oil viscosity and unfavourable rock wettability.
- Current EOR Limitations: Existing synthetic polymers (e.g., HPAM) are prone to degradation in harsh reservoir environments (high temperature/salinity) and are not eco-friendly.
- The Solution: Propose a novel, eco-friendly biopolymer blend (PB) composed of Guar Gum (GG) and Acetylated Guar Gum (aGG) to overcome these issues.



Graphical Abstract. Chemical modification and blending of biopolymers enhances viscosity control, reduces interfacial tension, and shifts carbonate rock surfaces from oil-wet to water-wet, enabling improved oil mobility and higher recovery in EOR

METHOD

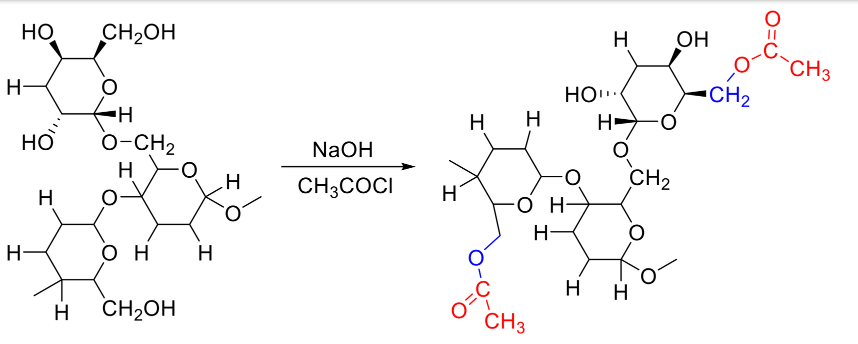


Fig. 1. Schematic of guar gum acetylation under reflux (50 °C, 4 h, N_2), where hydroxyl groups are substituted by acetyl groups to form acetylated guar gum (aGG).

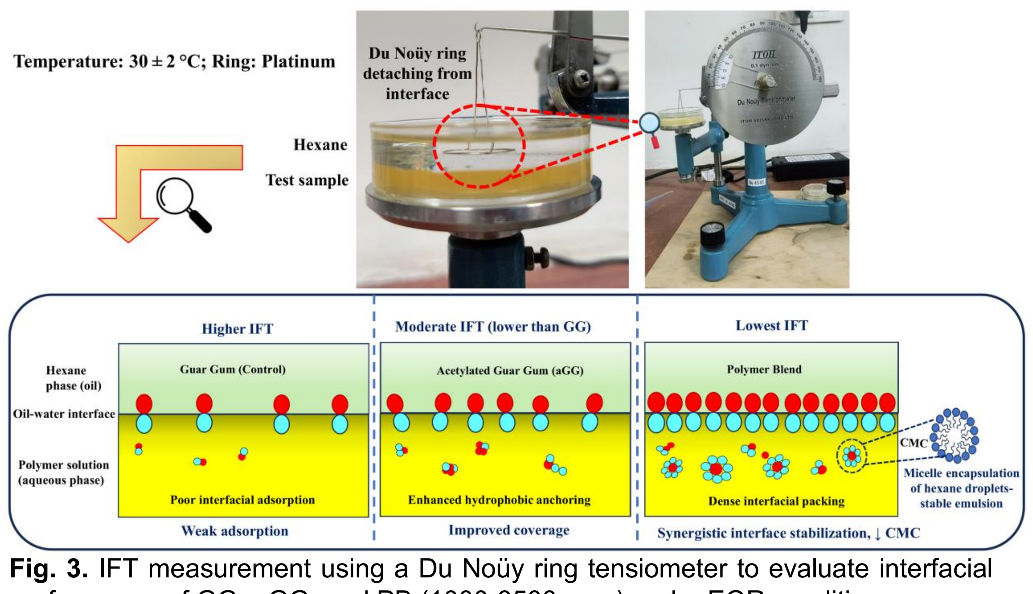


Fig. 3. IFT measurement using a Du Noüy ring tensiometer to evaluate interfacial performance of GG, aGG, and PB (1000-3500 ppm) under EOR conditions

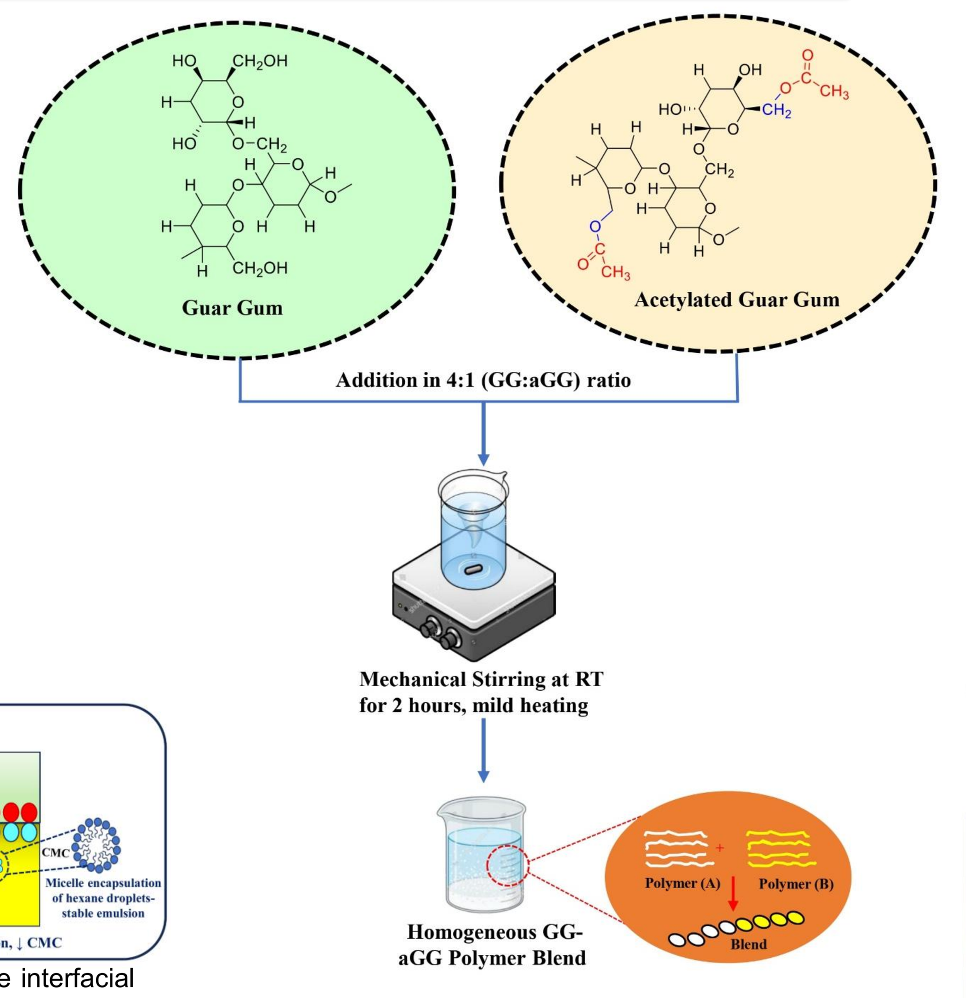


Fig. 2. Synthesis of the GG-aGG (4:1) blend under mechanical stirring to obtain a homogeneous, air-free polymer solution for EOR.

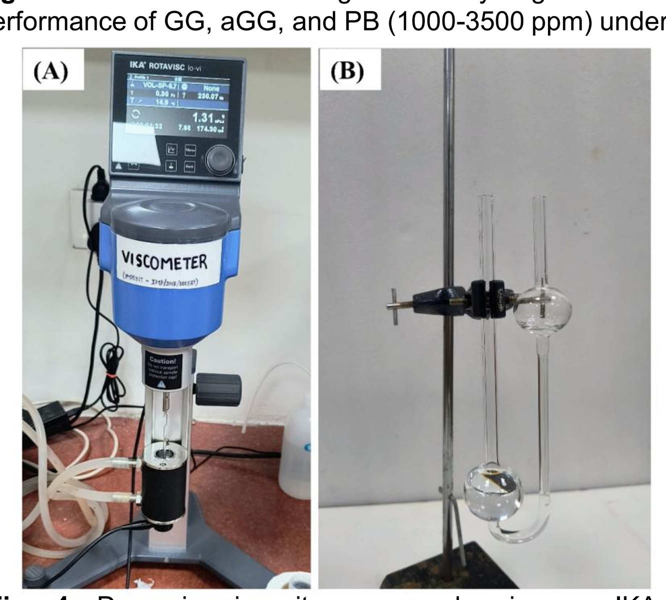


Fig. 4. Dynamic viscosity measured using an IKA viscometer and kinematic viscosity using an Ostwald viscometer.

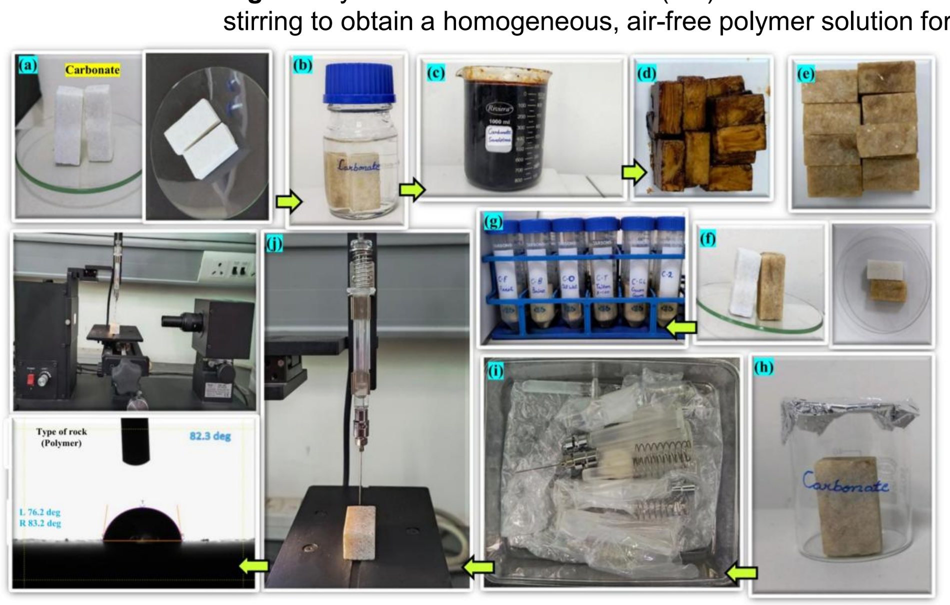


Fig. 5. Workflow for wettability alteration studies using a goniometer.

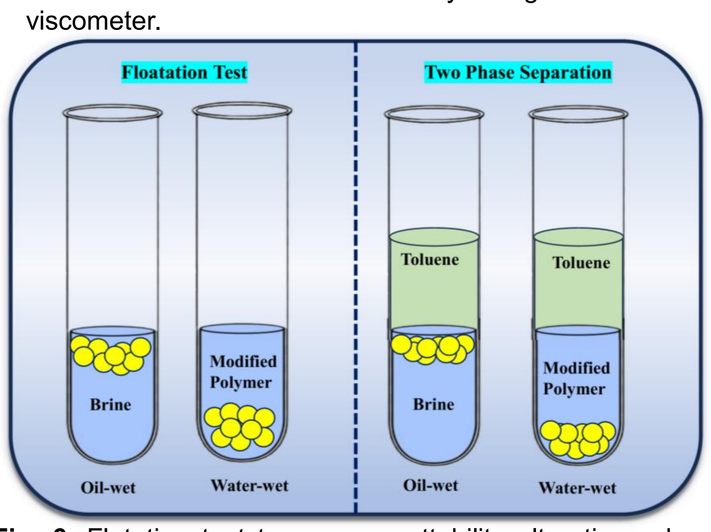


Fig. 6. Flotation test to assess wettability alteration, where polymer-treated oil-aged carbonate particles either float (oil-wet) or sink (water-wet) in a toluene-brine system.

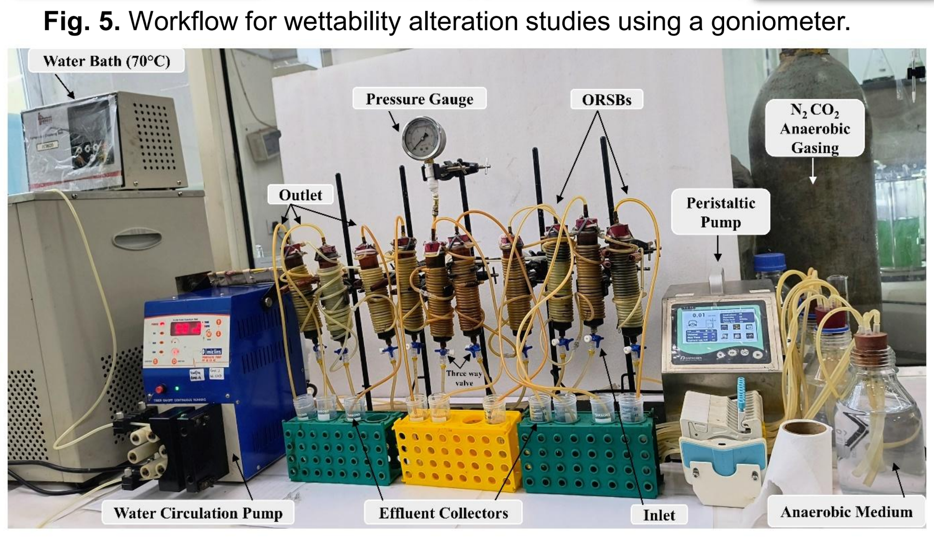


Fig. 7. Oil Reservoir Simulating Bioreactor (ORSB) setup used to evaluate the EOR performance of GG, aGG, and PB under controlled temperature, flow, and pressure conditions.

RESULTS & DISCUSSION

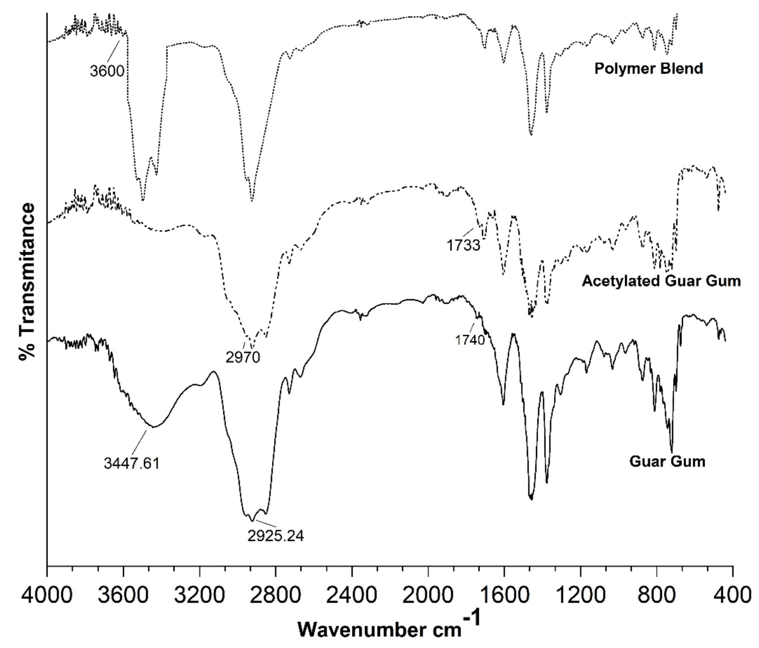


Fig. 8 FTIR spectrum of different polymers (GG, aGG and PB)

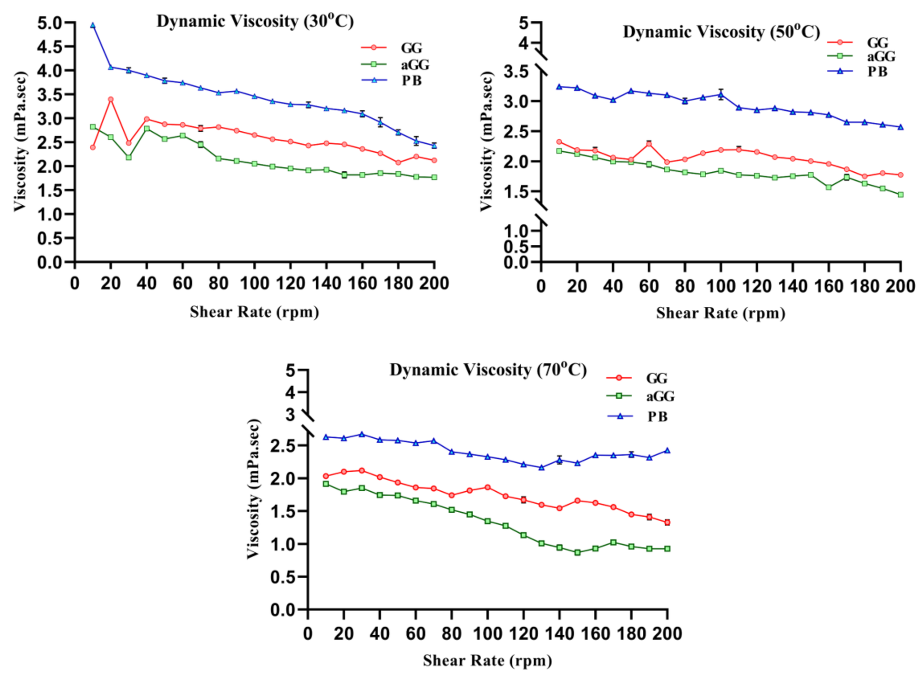


Fig. 9 Variation in viscosity of GG, aGG and PB with different shear rate and with different temperature 30°C, 50°C, 70°C

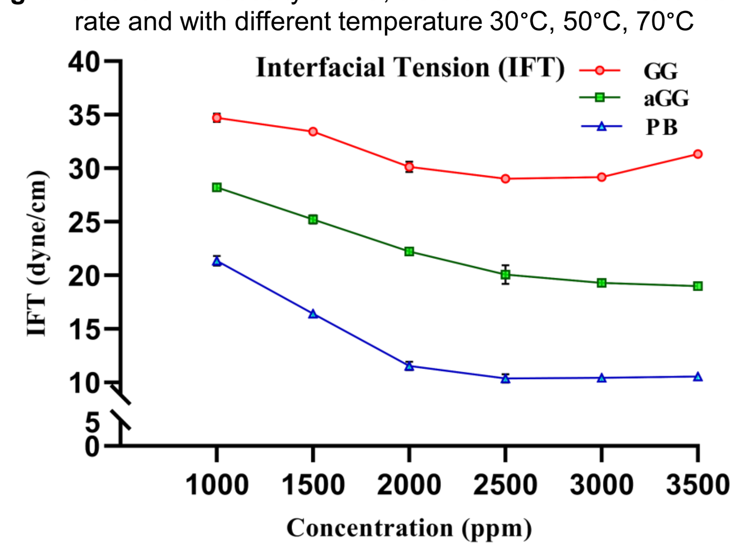


Fig. 10 Variation of IFT with different concentration of GG, aGG and PB

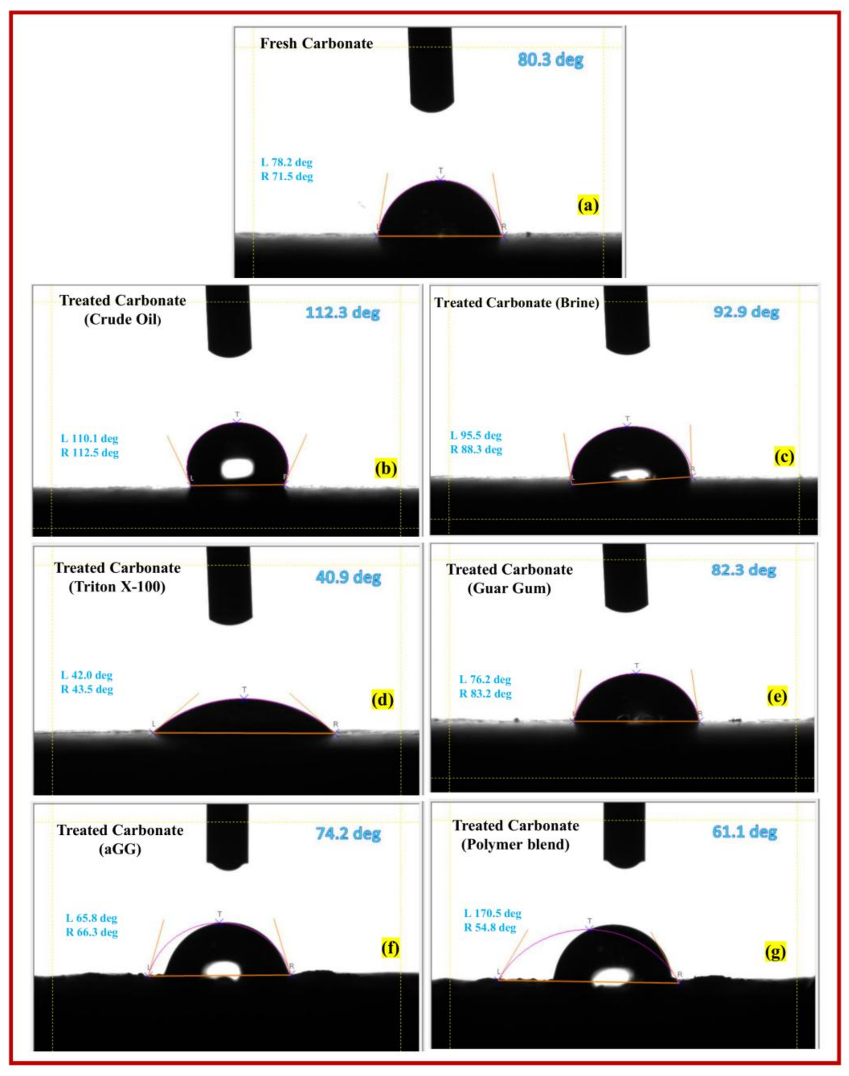


Fig. 11. Contact angle results showing enhanced wettability alteration, with the PB-treated carbonate surface exhibiting the greatest shift toward water-wet conditions

Standard Curve

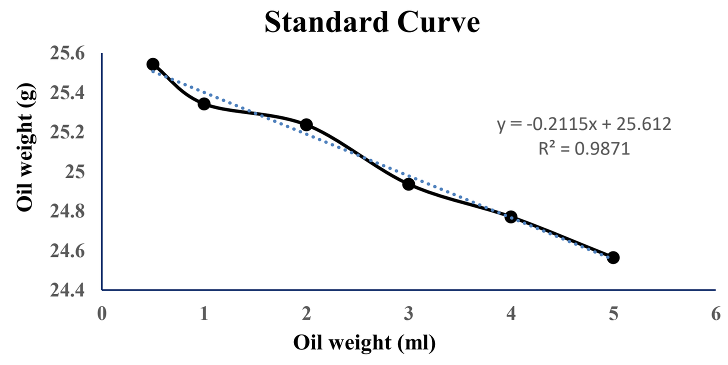
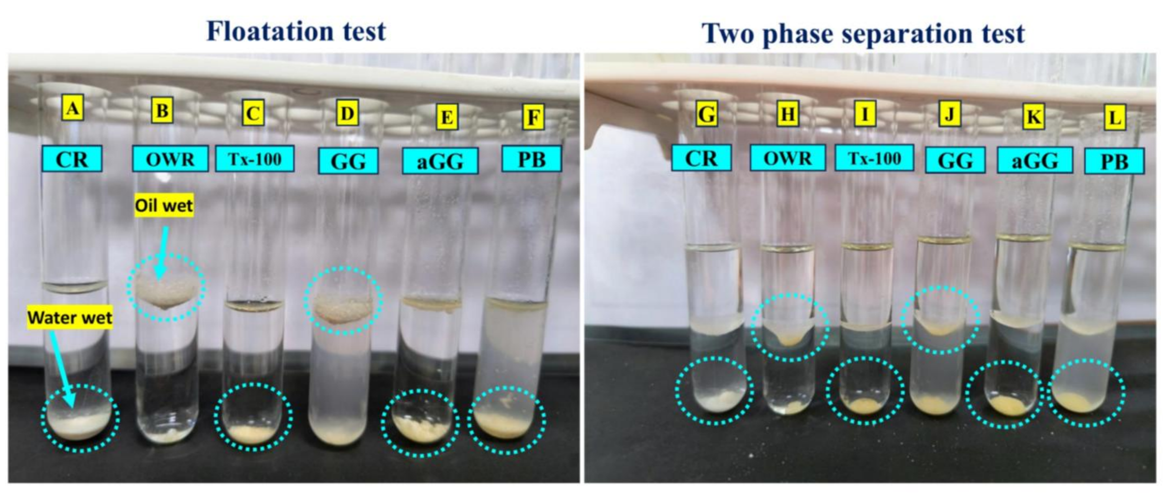


Fig. 14. Standard curve showing the relationship between oil volume (mL) and oil weight (g)



CR- Calcite Rock; OWR- Oil-Wet Rock; TX-100- Triton-X-100; GG- Guar gum; aGG- Acetylated guar gum; PB- Polymer blend

Fig. 12. Qualitative flotation and two-phase separation tests showing that the polymer blend most effectively shifts oil-wet calcite particles toward water-wet behavior compared to GG, aGG, and Triton X-100.

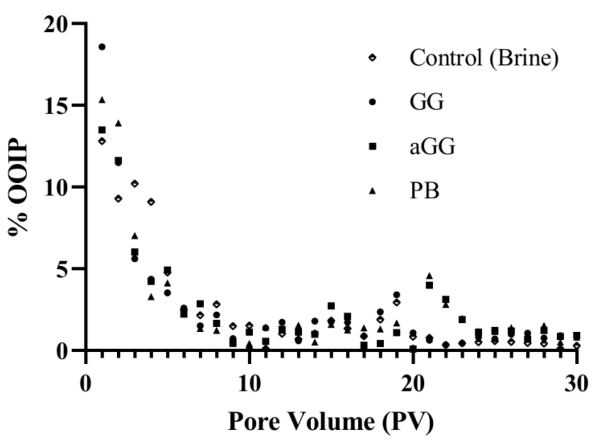


Fig. 15. Recovery efficiency (%OOIP) plotted as a function of injected pore volumes

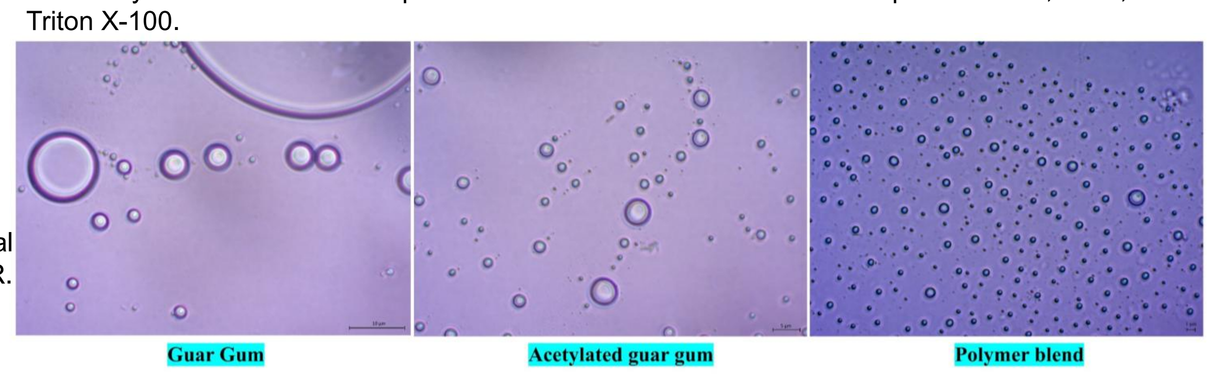


Fig. 13. Emulsification comparison showing PB forms smaller, uniformly dispersed oil droplets, indicating superior emulsion stability over GG and aGG.

Oil Recovery

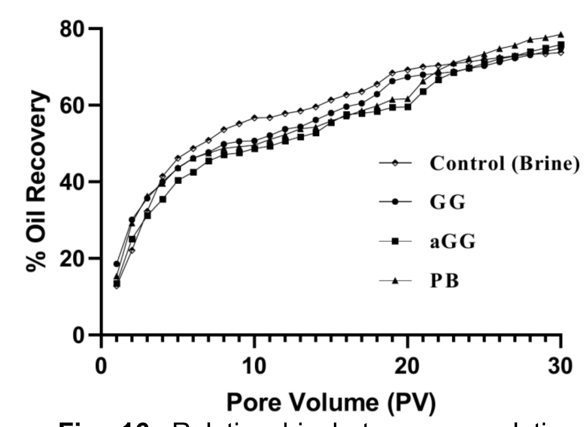


Fig. 16. Relationship between cumulative oil recovery (%) and pore volume injected during the displacement process

CONCLUSION

- **Superior Performance:** HPMP achieved 8.31% incremental oil recovery
- **Wettability Conversion:** Blend effectively converted the carbonate rock from oil-wet (112.3°) to water-wet (61.1°).
- **Rheological Advantage:** Exhibits pseudoplastic (shear-thinning) flow, improving injectivity and reservoir sweep.
- **Translational Impact:** Cost-effective alternative to synthetic polymers; resists degradation in harsh reservoirs. Eco-friendly biopolymer from renewable sources promotes sustainable energy recovery.

FUTURE WORK / REFERENCES

- **Pilot Field Trials:** Conduct high-pressure, high-temperature (HPHT) field trials to validate HPMP performance in a live reservoir environment.
- **Commercial Viability:** Perform detailed techno-economic (cost-benefit) and Life Cycle Analysis (LCA) for industrial deployment.