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EXTRACTION OF GREEN GRASS JELLY LEAVES AS AN ALTERNATIVE BIOPOLYMER IN POLYMER FLOODING

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ABSTRACT
Biopolymer from Green Grass Jelly Leaves attracts attention due to its friendlier environmental profile and cost-effectiveness in providing raw materials. This research aims to explore the potential of biopolymers from Green Grass Jelly Leaves as an alternative to synthetic polymers in an effort to increase oil recovery involving sequential pretreatment, extraction, and characterization stages to obtain essential pectin compounds. This experiment centers on a biopolymer sourced from Green Grass Jelly Leaves, involving sequential steps of pretreatment, extraction, and characterization to obtain essential pectin compounds. Characterization employed scanning electron microscopy (SEM) and Fourier-transform infrared spectroscopy (FTIR). The recorded peak viscosity for Green Grass Jelly Leaves biopolymer was 2.04 cp at 3000 ppm concentration, contrasting with pectin's 1.98 cp viscosity. In comparison, industrial biopolymer Xanthan Gum displayed significantly higher viscosity at 95.01 cp for 3000 ppm concentration. Thermal stability assessment under reservoir conditions (30°C and 60°C) demonstrated that Green Grass Jelly Leaves biopolymer pectin exhibited peak viscosities of 55.29 cP and 51.77 cP at 3000 ppm concentration, respectively. These results show that the comparison between biopolymer and synthetic polymer is not too far and there is an increase in viscosity as the concentration increases, which can increase sweep efficiency.
Keywords: *Green Jelly Leaves, Sweep Efficiency, Pectin,*

1. Introduction

To increase oil production, which is experiencing a decline, Enhanced Oil Recovery (EOR) techniques are very important. One of the effective EOR methods is Polymer flooding, which can increase oil sweeping efficiency by increasing its mobility when oil permeability is lower than water permeability (Erfando & Khariszma, 2023; Lake et al., 2014). In the petroleum industry, there are two types of polymers that are commonly used, namely synthetic polymers and natural polymers (biopolymers). Many synthetic polymers derived from petroleum and coal are known to pose environmental risks because they are less biodegradable. Therefore, the focus is currently shifting to the use of biopolymers derived from renewable sources such as starch, cellulose, chitin, chitosan, zein, and gelatin (M. K. Afdhol et al., 2019; M K Afdhol et al., 2020; Muhammad Khairul Afdhol et al., 2020; Fadly et al., 2022; Jacob & Gopi, 2021).

Biopolymers, whether obtained naturally or via synthetic routes, demonstrate significant advantages over petroleum-based biopolymers, including cost-effectiveness, environmental sustainability, and more user-friendly materials. Based on previous studies, Xanthan Gum has been mostly used as primary biopolymer in improving recovery in oil wells. As a class of polysaccharide polymers, Xanthan Gum has a very effective suspension capacity, increasing the efficiency of the Enhanced Oil Recovery (EOR) process by retaining particles in solution without significant sedimentation (Nsengiyumva & Alexandridis, 2022; Pu et al., 2018). In Said et al. (2021) research, at a temperature of 80 ◦C with a shear rate of 0.01 s^{-1}, the viscosity of xanthan gum reached 10.41 cp. Xanthan gum's good thickening ability helps increase the viscosity of water and makes it thicker so it can help push oil to the surface (Muhammed et al., 2020). Xanthan Gum's emulsifying properties also aid in mixing the oil and solution during the EOR injection process, allowing for more efficient oil extraction. Xanthan Gum is water soluble with a high molecular weight, usually around 1–50 × 106 g/mol) (Fink, 2015; Holzwarth, 1978). The viscosity of 1 g/L Xanthan gum is between 13–35 cp and the viscosity are stable at low pH values (up to pH 3), high salinities (up to 3% salt), and temperatures (up to 80 ◦C) (García-Ochoa et al., 2000; Patel et al., 2020). This stability against pH variations is very important to maintain its performance in reservoir conditions that have fluctuating pH. Xanthan gum has the ability to maintain its stability at a reservoir temperature of 120 ◦C because at this temperature xanthan gum has effective viscoelastic and pseudoplastic properties (Navaie et al., 2022; Nnyigide & Hyun, 2023; Oviatt & Brant, 1994). With these properties, Xanthan gum can change the nature of fluid flow in reservoirs and reduce water mobility so that Xanthan gum is able to maximize oil production efficiently.

However, Xanthan gum also has significant limitations such as a not very good thickening effect and the presence of a conformational transition temperature. According to de Moura & Moreno (2019) xanthan gum is unable to form complex bonds through macromolecular interactions in its suitable configuration, resulting in thermal disruption and a decrease in viscosity values. In addition, limited temperature and salt tolerance limits its application to high temperatures and reservoirs with high salt content (Fu et al., 2022; Li et al., 2021).

Therefore, research was carried out on pectin from green grass jelly leaves as an alternative base material for polymers from the polysaccharide group which could facilitate the development of better biopolymers in the future. Pectin ($C6H10O7$, M.W. 194.14 g/mol), an anionic biopolymer whose main use is in the field of agricultural industrial waste, pharmacy (Günter & Popeyko, 2016), cosmetics (Lupi et al., 2015), Food or drug packaging (Martau et al., 2019), and polymer (da Costa et al., 2016). Until now there has been no research on the use of pectin in the petroleum sector, although according to GENERAL STANDARD FOR FOOD ADDITIVES (1995), Pectin is characterized as an emulsifier, gelling agent, stabilizer, and/or thickener in commercial applications, where these characteristics are of great benefit in optimizing sweep efficiency and maximizing oil recovery. In food technology or formation, Pectin is a non-toxic compound that can survive in the large intestine (Martau et al., 2019; Paharia et al., 2007; Sungthongjeen et al., 1999) which means, pectin can survive at low pH and can be used in oil reservoirs that also have extreme pH. Based on several rheological tests of pectin-based biopolymers (M. K. Afdhol et al., 2023; Chan et al., 2017; Martau et al., 2019; Perdana et al., 2023) provided promising results that can be used to increase oil recovery in the oil industry.

Green grass jelly leaves are a type of plant with complex polysaccharides as plant cell walls (Mohnen, 2008; Yapo et al., 2007). Green grass jelly leaves contain about 15.2% pectin, making them an ideal candidate to be a biopolymer (Elsyana & Alvita, 2022). The polymer produced from green grass jelly leaves is a type of pectin polysaccharide Pectin group of polymer-producing polysaccharides belongs to 3 main groups of polymers, namely: homogalacturonan, rhamnogalacturonan 1, and galacturonan derivatives (Ridley et al., 2001). In general, pectin is found in the primary cell walls of plants, especially on the sidelines between cellulose and hemicellulose. Pectin is a water-soluble polysaccharide (WSP), and its most significant use is as a stabilizer and viscosity control (Siew et al., 2008).

The extraction process to produce pectin for polymers has several procedures that must be carried out, including the pretreatment process, the extraction process, and the polymer testing process (Agi et al., 2020; Lestari et al., 2020). Testing of polymer gel resulting from pectin extraction was carried out to determine the characteristics of the gel (Abid et al., 2016; Brown et al., 2014; Ceballos et al., 2016; Rascón-Chu et al., 2009; Yuliarti & Mardyiah Binte Othman, 2018). The tests include testing for compatibility, Viscosity, Salinity, thermal, and shear rate (Agi et al., 2020).

This research focuses on the synthesis of biopolymers from green grass jelly leaves to improve EOR techniques. It is hoped that the use of natural raw materials can optimize oil extraction efficiency without sacrificing environmental factors and production costs. This study also explores the pectin extraction process, tests the characteristics of the extracted polymer gel, and analyzes the impact of its use in the EOR process.

2. Research Methods

Green grass jelly leaves were chosen as an alternative biopolymer in this research because green grass jelly leaves (Cyclea barbata) contain abundant pectin. Green grass jelly leaves contain about 15.2% pectin, making them an ideal candidate (Elsyana & Alvita, 2022). Apart from that, easy access to these leaves in Indonesia also plays an important role in choosing these leaves as the basic material for the biopolymer manufacturing process. These plants are primarily found in

Southeast Asian countries such as India, Malaysia, Indonesia, and Thailand (Yuliarti & Mardyiah Binte Othman, 2018).

The method used in this study was an experimental laboratory method by extracting Green Grass Jelly Leaves to produce biopolymer. The biopolymer produced will be characterized by SEM & FTIR tests, then tested by testing Compatibility, Viscosity, Thermal, Salinity, and Shear Rate. Materials used include Green Grass Jelly Leaves. Ascorbic Acid, Vinnegar, Ethanol 94%, Xanthan Gum, Aquadest.

- Pretreatment
  The pretreatment process is done to get pectin. The pretreatment process was carried out by drying the Green Grass Jelly Leaves to be crushed and then filtered with a 230 mesh.
- Extraction
  The extraction process is carried out by dissolving Green Grass Jelly Leaves powder in 1 liter of aquadest, adding vinegar and 100 ml of alcohol. Adding ascorbic acid to the solution at a ratio of 1:10 (v/v). Then stir using a magnetic stirrer at a speed of 1100 rpm at a temperature of 60oC for 120 hours. After that, the solution was sonicated in an ultrasonic bath with a frequency of 40 kHz at a power of 500 W for one hour. Centrifuge the resulting solution to obtain polymer particles. Clean the polymer particles three times to remove alcohol, free surfactants, acids, vinegar, and air dry (Agi et al., 2020).
- Characterization
  Conduct characterization tests by conducting a Scanning Electron Micrograph (SEM) to determine the physical structure and surface morphology of the polymer formed (A.Z. Abidin, Puspasari, & Nugroho, 2012) and a Fourier Transform Infrared (FTIR) to find out whether a polymer is formed by looking at the groups that appear on the polymer (A Zainal Abidin, Susanto, Sastra, & Puspasari, 2012). SEM uses a flow of electrons in a scanning electron microscope to depict the surface and structure of a sample in detail (Ul-Hamid, 2018). Samples tested using the SEM technique must be smooth and removed from water or moisture (Fratesi, Lynch, Kirkland, & Brown, 2004). The parameters analyzed in SEM testing are the structure of polymer particles at 1000x magnification. FTIR uses an infrared spectrophotometer to measure molecular interactions in samples (Friese, Banerjee, & Mangin, 2020). Samples tested using the FTIR technique are placed in a cell or cup that is transparent to infrared rays such as glass and the sample must be dry to avoid water absorption (Perkins, 2020). The parameters analyzed in FTIR testing are chemical bonds, functional groups, identification of organic and inorganic compounds, and molecular structure (Zhao et al., 2020).
- Rheology Test
  Rheology Testing consists of several types of tests, namely:
  a. Compatibility testing, to see whether precipitate formed at room temperature, which was observed for several days (Mady et al, 2020).Compatibility testing is important to maintain the effectiveness of the EOR process so that the solution does not clump which can block rock pores.
  b. Viscosity testing, useful for determining the viscosity of a solution or fluid using ASTM D445. The ASTM D445 standard is used as the international standard for measuring kinematic viscosity in petroleum (Khuu et al., 2019). The first thing that needs to be done is to clarify the Ostwald viscometer and then insert the sample into the viscometer until the container is full. Sucking fluids with a pushball to the upper limit. Measure the speed of the liquid flowing with a stopwatch from the upper limit to the lower limit. Viscosity testing is a critical aspect in achieving the main objective of this research because viscosity is related to other parameters.
  c. Doing the Shear Rate Test using the Vann VG Meter, we first put the liquid sample into the circulating cup up to the specified limit. Position the circulating cup on the VG meter fan, then adjust the position of the rotor and bob until it is immersed in the liquid up to the specified limit. Move the rotor to the High position and set the rotor speed at 600 RPM. Wait until the position of the scale (dial) reaches balance. Then record the value indicated by the scale. Do the same for the 300 RPM speed. The viscosity value is obtained by the equation (τ /γ) x100. Shear stress is obtained by the equation $\tau = 5{,}077 \times C$, and the shear rate is obtained by the equation $\gamma = 1{,}704 \times RPM$.

d. The biopolymer salinity test was carried out by looking at the viscosity value of the polymer at various salinity levels, namely 5000 ppm, 10,000 ppm, and 15,000 ppm (Obuebite et al., 2018). The thermal stability test is carried out by testing the Viscosity of the polymer when it is heated at the reservoir temperature (Mady et al., 2020). Salinity and thermal tests are carried out to test the stability of the polymer at high levels of salinity and temperature, as well as to prevent the potential for the solution to split during the polymer injection stage.

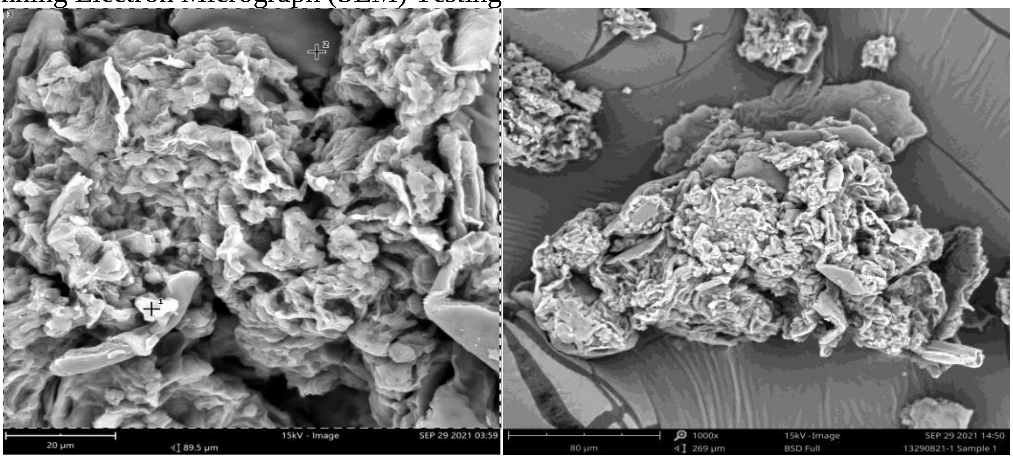
3. Results and Discussions

a. Green Grass Jelly Leaves Pectin Extraction

Pectin is obtained from extracting Green Grass Jelly Leaves by soaking in 1 liter of distilled water which is then added with vinegar, 94% ethanol, and 1:10 V/V ascorbic acid. The higher the pectin concentration, the higher the modulus/elasticity. At the same time, temperature changes affect the pectin molecular characteristics and the rheology (Yuliarti & Mardyiah Binte Othman, 2018).

b. Characterization

- Scanning Electron Micrograph (SEM) Testing



(a)   (b)

Fig. 1. SEM Test Results for Green Grass Jelly Leaves Pectin.

Figure 1(a) shows a magnification of 3000x that the polymer group bonds are fused but with an irregular shape. This indicates that the polymers are not tightly bound to each other due to the irregular shape and arrangement of the polymer groups.

Figure 1(b) shows the shape of the polymer at 1000x magnification which looks like a round oval but is not flat. This is caused by the heating process, which makes the shape irregular (Diop, Li, Xie, & Shi, 2011). The shape of the particles after extraction is strongly influenced by the temperature during the synthesis process (Ku & Maynard, 2005).

Table 1 - SEM Test Results For Green Grass Jelly Leaves Pectin.

Element Number	Element Symbol	Element Name	Atomic Conc.	Weight Conc.
6	C	Carbon	56.64	49.75
8	O	Oxygen	32.38	37.88
7	N	Nitrogen	10.02	10.26
19	K	Potassium	0.36	1.02
12	Mg	Magnesium	0.30	0.54
11	Na	Sodium	0.21	0.36
14	Si	Silicon	0.09	0.18

From the Table 1, after magnification of 3000x, the element carbon has the highest value, followed by oxygen. The presence of carbon and oxygen elements in the polymer indicates the formation of various chemical linkages, such as carbon-oxygen single bonds (C-O) or carbon-oxygen double bonds (C=O), which contribute to the overall strength of the polymer structure (Carraher Jr., 2007). The strong bond between carbon and oxygen plays a vital role in determining the polymer's physical properties and performance characteristics. For instance, it can influence the polymer's tensile strength, flexibility, and resistance to chemical degradation. Additionally, such strong polymer bonds enhance the material's overall durability and ability to withstand external stressors (Clark, 1985).

- Fourier Transform InfraRed (FTIR) Testing

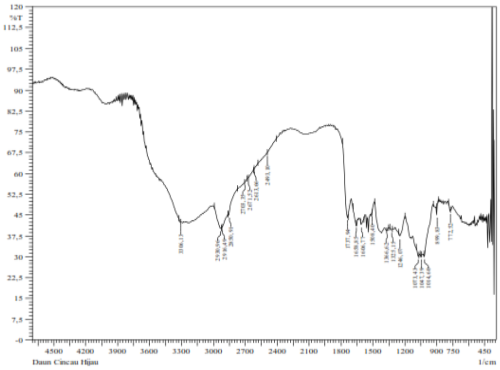


Fig. 2. Ftir Test Results for Green Grass Jelly Leaves.

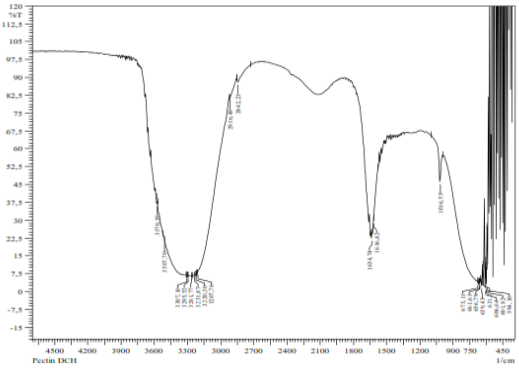


Fig. 3. FTIR Test Results of Green Grass Jelly Leaves Pectin.

The Green Grass Jelly Leaves Pectin test results in Figure 3 show a wide arc in the 3600-3000 1/cm region. In the Green Grass Jelly Leaves test in Figure 2, there is a bend in the 3600-3300 1/cm area. This indicates the presence of OH groups between the two samples, but a stronger intensity is shown by Green Grass Jelly Leaves Pectin (Fauziah et al., 2016). The increase in the peak value was caused by the hydrolysis and sonication processes (Agi et al., 2020). For the spectrum of Green Grass Jelly Leaves Pectin, the peak spectrum of 1634.74 indicates the presence of a C=O bond which indicates the presence of carboxyl and carbonyl groups (Liang et al., 2016). The carboxyl and carbonyl groups successfully oxidize during synthesis (Agi et al., 2020).

c. Compatibility Testing

Biopolymer test results after the extraction process were tested by leaving the solution at room temperature for several days. This aims to determine the results of the biopolymer, whether there is sediment or not when it is allowed to stand and to find out how the solubility of the biopolymer is in water.

Table 2 - Compatibility Test Results.

No	Sample		Result Test	
1		1000	A bit clear	No sediment
2	Xanthan Gum	2000	Muddy	No sediment
3		3000	Muddy	No sediment
4		1000	Clear	Sediment
5	Green Grass Jelly Leaves	2000	A bit Clear	Sediment
6		3000	Muddy	Sediment
7		1000	Clear	Sediment
8	Green Grass Jelly Leaves Pectin	2000	Clear	Sediment
9		3000	Clear	Sediment

From the test above, it is known that Xanthan Gum does not have sediment during testing. In line with the requirements of the EOR technique, namely, the injected solution must be compatible with water and have no clumping. According to Obuebite et al. (2018), a solution with good compatibility is a solution that is clear and has no sediment. Green grass jelly leaves pectin has a clear solution with little sediment resulting from the extraction process. In the polymer injection process, excessive and uncontrolled deposition can cause blockages in rock pores.

d. Viscosity Test

Many studies in the petroleum sector use ASTM D445 as a standard in measuring viscosity (Huang, Li, Bao, Wang, & Wang, 2020; Mousavi, Zeinali Heris, & Estellé, 2021; Sentanuhady et al., 2020). ASTM D445 viscosity standard measurement by determining the kinematic viscosity of transparent and turbid petroleum products using a glass capillary viscometer, which measures the flow time of liquids flowing by gravity, is useful for estimating optimal storage, handling, and operational conditions for petroleum products and non-petroleum (Khuu et al., 2019). Below are the results of the Viscosity test for Xanthan Gum (XG), Green Grass Jelly Leaves (GGJL), and Green Grass Jelly Leaves Pectin (GGJLP).

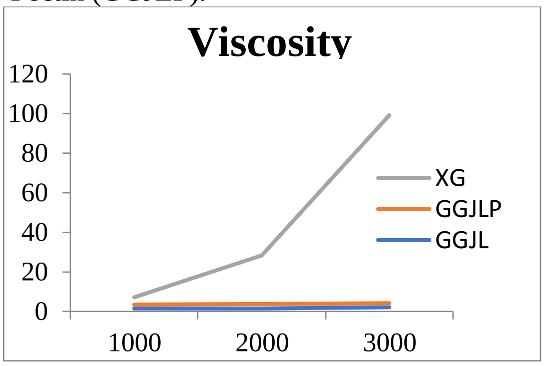


Fig. 4. Viscosity Test Results Of Xanthan Gum (XG), Green Grass Jelly Leaves (GGJL), Green Grass Jelly Leaves Pectin (GGJLP).

The presented graph depicts the Viscosity behavior of Xanthan Gum at a concentration of 3000 ppm, revealing a significantly high viscosity of 95 cp. In the assessment of Green Grass Jelly Leaves and Green Grass Jelly Leaves Pectin at the same concentration, it is evident that they exhibit varying viscosities, with the former displaying the highest viscosity. When evaluating green grass jelly leaves and green grass jelly leaves pectin at the same concentration, they both show different viscosities, with the highest value being 2.04 cp for green grass jelly leaves pectin and 1.98 cp for green grass jelly leaves. Furthermore, a research study conducted by Khalid, Lestari, Afdhol, & Hidayat (2020) that specifically investigated cotton leaf extraction reported a measured viscosity of 1.05 cp at a concentration of 3000 ppm. Therefore, the higher the polymer concentration, the higher the viscosity value. These findings align with the theoretical framework expounded in the scholarly publication by (Agi et al., 2020). In the polymer injection process, the increased viscosity helps control the mobility and movement of water. This can increase the contact between the water and oil solutions so that the washing of the oil by the water becomes more effective.

e. Salinity Test

Salinity testing aims to determine the Viscosity of Xanthan Gum and Green Grass Jelly Leaves Pectin with concentrations of 1000, 2000, and 3000 in water with a salinity of 5000, 10000, and 15000 ppm.

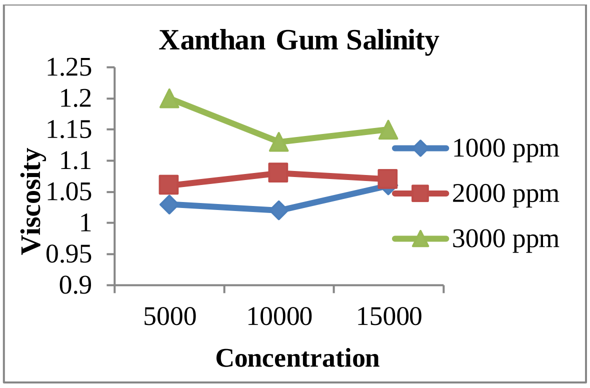


Fig. 5. Xanthan Gum Salinity Test Graph.

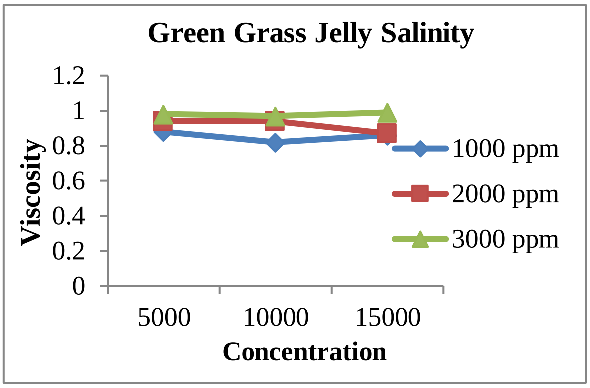


Fig. 6. Green Grass Jelly Leaves Salinity Test Chart.

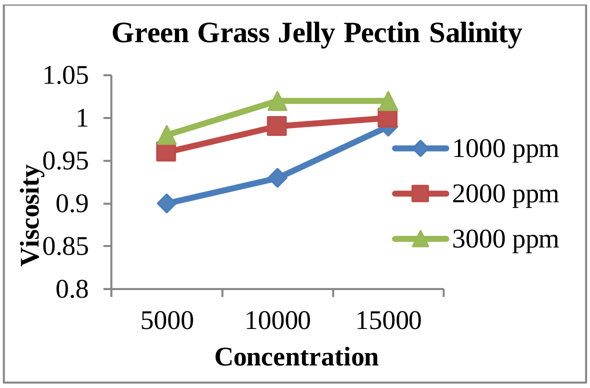


Fig. 7. Green Grass Jelly Leaves Pectin Salinity Test Chart.

Upon analyzing the presented graph, a comparative evaluation of the salinity examination results on three distinct samples, namely xanthan gum, green Grass Jelly Leaves, and Green Grass Jelly Leaves Pectin, reveals a noteworthy decline in the viscosity of xanthan gum. The salinity test outcomes for the Green Grass Jelly Leaves indicate a relatively consistent and moderately insignificant reduction in viscosity. Conversely, the salinity test performed on the Green Grass Jelly Leaves Pectin sample demonstrates a substantial and abrupt alteration in viscosity between the samples at 3000 ppm and 1000 ppm. However, for concentrations ranging from 3000 ppm to 2000 ppm, the disparity in viscosity is comparatively minor. Compared with Khalid et al. (2020) research, the comparative analysis reveals that the salinity measurement within cellulose cotton leaves exhibits a recorded value of 0.48 cp at a concentration level of 3000 ppm. These findings suggest a clear correlation between the concentration of the substances and their viscosity in the presence of different salinity levels. As the salinity increased, the viscosity decreased across all concentrations (Khalid et al., 2020; Lestari et al., 2020). This information is crucial for understanding the behavior of xanthan gum and green grass jelly leaves pectin in different saline environments. It can be utilized to optimize formulations in various industries, such as food processing or pharmaceuticals, where the viscosity of substances plays a vital role in product quality and stability.

f. Shear Rate Test

The shear rate tests conducted on Green Grass Jelly Leaves Pectin, Green Grass Jelly Leaves, and Xanthan Gum samples at various concentrations revealed significant findings. It was observed that an increase in shear rate resulted in a decrease in sample viscosity. Comparing the samples at a higher concentration of 2000 ppm to the lower concentration of 1000 ppm, a consistent decrease in viscosity was observed across all shear rates for both the Green Grass Jelly Leaves Pectin and Green Grass Jelly Leaves samples. Conversely, the Xanthan Gum sample demonstrated higher viscosities at both 2000 ppm and 3000 ppm compared to the lower concentration of 1000 ppm.

The results of the research above show that the viscosity of all samples decreases with increasing shear rate. According to Khalid et al. (2020) and Li et al. (2021), viscosity decreases with increasing shear rate, indicating that the polymer solution is a pseudoplastic non-Newtonian solution. This is also explained by Abrahamsen (2012), due to its non-Newtonian nature, the polymer solution is advantageous because it can regain viscosity after decreasing at a high shear rate when injected into the well.

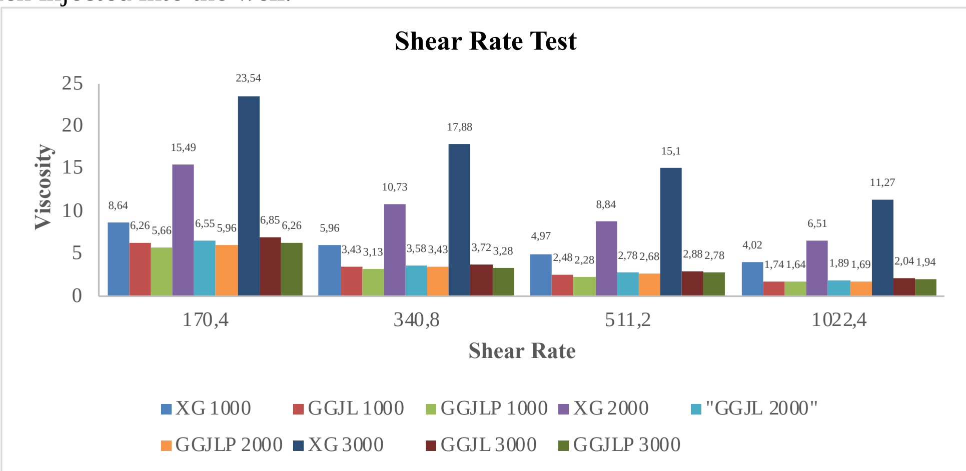


Fig. 8. Graph Of Testing Shear Rate 1000, 2000, And 3000 Ppm On Xanthan Gum (XG), Green Grass Jelly Leaves (GGJL), And Green Grass Jelly Leaves Pectin (GGJLP).

g. Thermal Test

Thermal tests were carried out using a Redwood viscometer with temperatures of 30°C and 60°C to see the resistance of the polymer at reservoir temperature. Viscosity is only allowed by 20% to decrease when the temperature increases (Gajah, Susantry, Arifin, Ramas, & Hidayat, 2019).

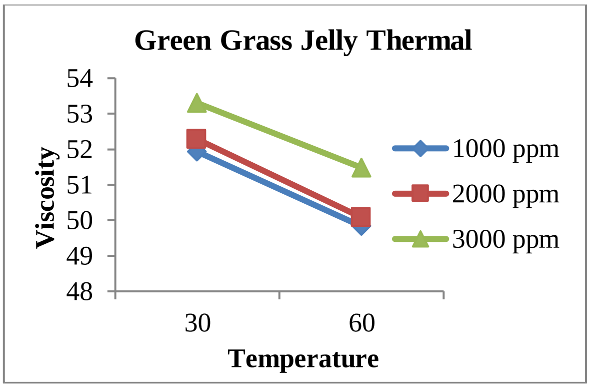


Fig. 9. Green Grass Jelly Leaves Thermal Test Chart.

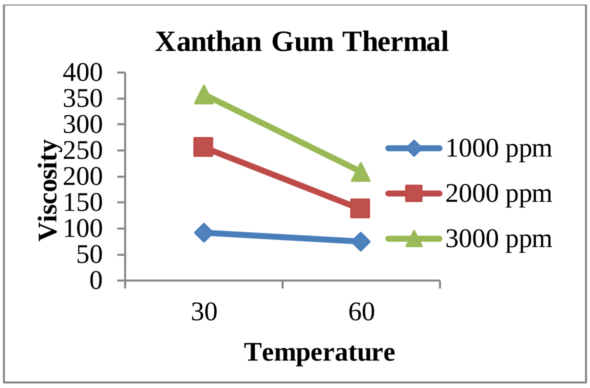


Fig. 10. Xanthan Gum Thermal Test Chart.

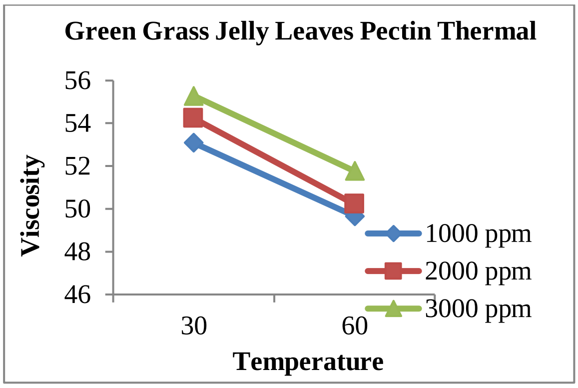


Fig. 11. Green Grass Jelly Leaves Pectin Thermal Test Chart.

The thermal testing of Green Grass Jelly Leaves was conducted to evaluate its viscosity properties at temperatures of 30 °C and 60 °C, employing concentrations of 1000 ppm, 2000 ppm, and 3000 ppm. The viscosity measurements obtained at 30 °C were 51.93 cp, 52.28 cp, and 53.3 cp for the respective concentrations. Similarly, at 60 °C, the viscosities recorded were 49.83 cp, 50.08 cp, and 51.48 cp for the same concentration range.

In the case of Xanthan Gum, the viscosity assessment was carried out at 1000 ppm, 2000 ppm, and 3000 ppm, with temperatures set at 30 °C and 60 °C. The recorded viscosity value at 30 °C and 60 °C for a concentration of 1000 ppm was 92.75 cp. Increasing the concentration to 2000 ppm yielded a significantly higher viscosity value of 256.137 cp. Furthermore, at a concentration of 3000 ppm, the viscosities were found to be 358 cp and 209 cp at 30 °C and 60 °C, respectively. For the Pectin sample, viscosity testing was conducted at 30 °C and 60 °C with concentrations of 1000 ppm, 2000 ppm, and 3000 ppm. The measured viscosities at 30 °C for the respective concentrations were 53.09 cp, 54.24 cp, and 55.29 cp. At 60 °C, the corresponding viscosities were 49.67 cp, 50.22 cp, and 51.77 cp. These results show a decrease in Viscosity with increasing temperature. Increasing temperature causes increased mobility of particles resulting in decreased interactions between particles. This causes the roll of polymer macromolecules that form the Viscosity to decrease (Agi et al., 2020). The high temperature weakens the hydrogen bonds between the polymer and water, thereby reducing the Viscosity (Maurya & Mandal, 2016)

4. Conclusion

From the results shown above, it can be concluded that from the Green Grass Jelly Leaves extraction process, it was possible to obtain pectin, which is a natural polymer from Green Grass Jelly Leaves. This biopolymer is proven to be able to increase the Viscosity as the concentration increases. Meanwhile, the biopolymer compatibility test on Green Grass Jelly Leaves is still not good when compared to xanthan gum. The results of the Green Grass Jelly Leaves pectin test also showed poor viscosity results when compared to the Green Grass Jelly Leaves viscosity. The shear rate test and thermal test on the three test samples above are classified as good because there is no significant decrease. Overall, the biopolymer produced from Green Grass Jelly Leaves can increase the Viscosity so that it has the potential to become an EOR and requires another research for its optimization.

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