

Studies in rheological behaviour of guar gum solution

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ABSTRACT

Guar gum is one of the largely available polysaccharide which is completely biodegradable, with high water absorption capacity. It is used in large many industrial, cosmetic, food and medical applications. 1 % guar gum solution in water is largely used for making any potential product from guar gum. Guar gum is processed by making a solution of it in dissolved water and subsequently blended or cross-linked or directly asked to prepare a required type of product. Thus, it's very important to understand the rheology of the guar gum to know its flow behavior during processing. This paper deals with the various rheological characteristics of 1 % guar gum solution in water. © 2014 Trade Science Inc. - INDIA

KEYWORDS

Guar gum;
Polysaccharide;
Rheology;
Water.

INTRODUCTION

Guar gum is a naturally occurring polysaccharide found in the endosperm of the seeds of *Cyamopsis tetragonalobus*. It is a chemically neutral, free-flowing, off-white colored powder^[1,2]. It is a hydrophilic heteropolysaccharide consisting of mannose and galactose monomer units. Mannose forms the backbone of the polymer linked together by β -1,4 glycosidic bonds. Galactose form branches onto the mannose backbone through α -1,6 glycosidic bonds. The mannose to galactose ratio of guar gum has been reported to be approximately 2 : 1^[3]. Guar gum has very high molecular weight of over 2 million. Because of very good hydrogen bonding and extensive intermolecular entanglement, guar gum produces very viscous solution with water^[4,5]. Water is a very good solvent for guar gum due to its ability to form strong hydrogen bonding

with water molecules^[6].

Guar gum is widely used in ice-creams for water crystal maintenance and functional food for adsorption of fats and sterols. It is also used in industrial applications like textiles^[7], explosives^[8], cosmetics^[9], mining^[10], etc, and pharmaceutical applications like drug delivery^[11,12], scaffolds^[13] etc. Lot of research is going on utilization of guar gum in preparation of hydrogels^[14-16]. Guar gum is a material of very commercial and academic importance. Guar gum is processed by making a solution of it in dissolved water and subsequently blended or cross-linked or directly asked to prepare a required type of product. Thus, it's very important to understand the rheology of the guar gum to know its flow behavior during processing.

There are few papers dealing with the rheology of guar gum, however they seem superficial^[17,18]. Whereas, many other deal with modified guar gum or the effect of

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addition guar gum in some other material^[15,19-24]. This paper is aimed to understand the rheological behavior of guar gum. Guar gum was subjected to

- 1) varying shear rate at different temperatures, and was noted for viscosity,
- 2) varying time at three constant shear rates, and was noted for viscosity,
- 3) Frequency sweep to know its loss modulus (LM), storage modulus (SM) and damping factor (DF)
- 4) LM, SM and DF at varying temperature, frequency maintained constant

MATERIALS AND METHOD

Materials

Guar gum was purchased from HiMedia Pvt Ltd. Mumbai, India. Distilled water was obtained from Bio Lab Diagnostics India Pvt. Ltd. (Mumbai, India). All materials were used as obtained without any modification.

Method

100 ml distilled water was taken in a beaker. It was added with 1 g guar gum. Mixture was stirred continuously at 1500 rpm for 10 h. It was added with 0.05 g of EDTA, to increase its shelf life. EDTA is a food grade preservative. Solution was again stirred for 2 h, to bring about uniform dispersion of EDTA in guar gum solution. 1 % guar gum solution is largely used in preparing guar gum films, hydrogels or to bring about any other modification. Prepared guar gum solution was utilized for rheological testing.

Characterization and testing

Rheological properties of guar gum solution were studied using an MCR 101 (Anton Paar, Austria). Cone and Plate assembly having diameter of 35 mm was used to apply shear rate and detect the viscosity. Distance between cone and plate was maintained constant at 0.147 mm. Data analysis was done using RHEOPLUS/32 V3.40 21004792-33024.

Effect of shear rate on viscosity of guar gum at constant temperature

Prepared guar gum solution was subjected to varying shear rates from 0.01 s⁻¹ to 1000 s⁻¹ at different tem-

peratures. Viscosity was determined at four different temperatures – 30, 40, 50 and 60 °C.

Effect of temperature on viscosity of guar gum at constant shear rate

Guar gum solution was subjected to varying temperature from 25 °C to 50 °C at constant shear rates. Samples were subjected to three constant shear rates – 0.1 s⁻¹, 5 s⁻¹ and 20 s⁻¹.

Effect of time on viscosity of guar gum at constant shear rate

Prepared guar gum solution was subjected to constant shear rates of 0.1 s⁻¹, 5 s⁻¹ and 20 s⁻¹ for 1200 s and its effect on viscosity was determined.

Frequency sweep at varied temperature

Guar gum solution was subjected to varying angular frequency from 0.5 to 80 s⁻¹ and its effect was analyzed on loss modulus, storage modulus and damping factor. Amplitude was maintained constant at 5%. Test was performed at four different temperatures - 30, 40, 50 and 60 °C. Damping factor is a ratio of loss modulus to storage modulus.

Effect of temperature on damping factor

Guar gum solution was subjected to varying temperature – 30 °C to 50 °C and its effect was determined on the loss modulus, storage modulus and damping factor at constant angular frequency. Test was performed at three different angular frequencies – 1, 6 and 20 s⁻¹.

RESULTS AND DISCUSSION

Effect of shear rate on viscosity of guar gum at constant temperature

Figure 1 plots the effect of shear rate on viscosity at different temperatures. Viscosity decreased with increase in shear. In addition, the decrease in viscosity is continuous and steady. Thus 1 % guar gum solution shows shear-thinning behavior. Decrease in viscosity was drastic at higher shear rates, which could be due to the rupture of the guar gum polymer chain arrangement caused by high shearing at high shear rates. Viscosity decreased with increase in temperature at same shear rates. Decrease in viscosity is more prominent at lower

shear rates; whereas, the difference is very small at higher shear rates, but the difference is still evident.

Temperature induced kinetic movement into the water and guar gum molecules, making them vibrate more compared to lower temperatures. This loosened the intermolecular forces of attraction between water/guar gum and guar gum/guar gum molecules, which decreased the resistance of the guar gum structure to the rotating motion of the spindle.

Effect of temperature on viscosity of guar gum at constant shear rate

Figure 2 plots the effect of temperature on viscosity of guar gum solution at different shear rates. Viscosity decreased with increase in temperature for the guar gum solution sheared at shear rate of 0.1 s⁻¹; whereas, it remained nearly constant for higher shear rates of 5 and 20 s⁻¹. Lower shear rate of 0.1 s⁻¹ is very low to bring about rupturing of the guar gum molecular arrange-

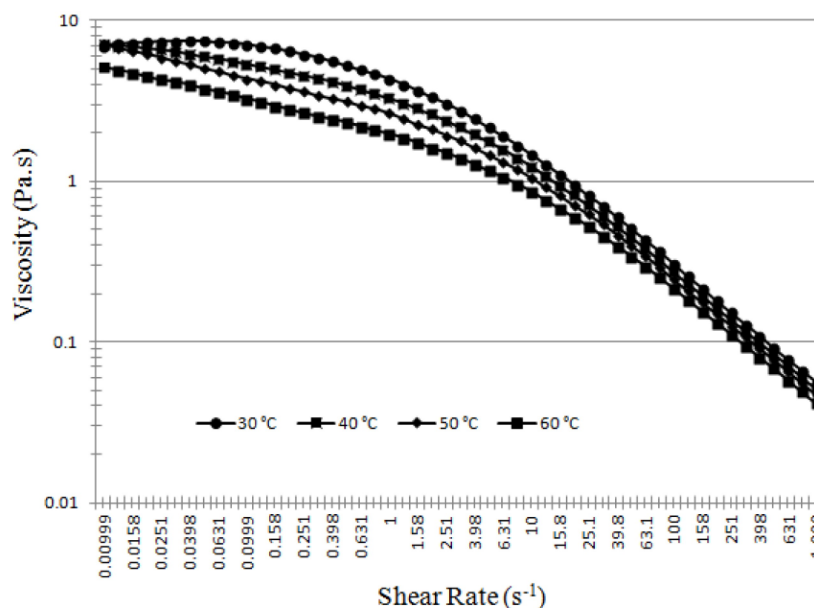


Figure 1 : Plot of viscosity (Pa.s) vs shear rate (s⁻¹) at different temperatures

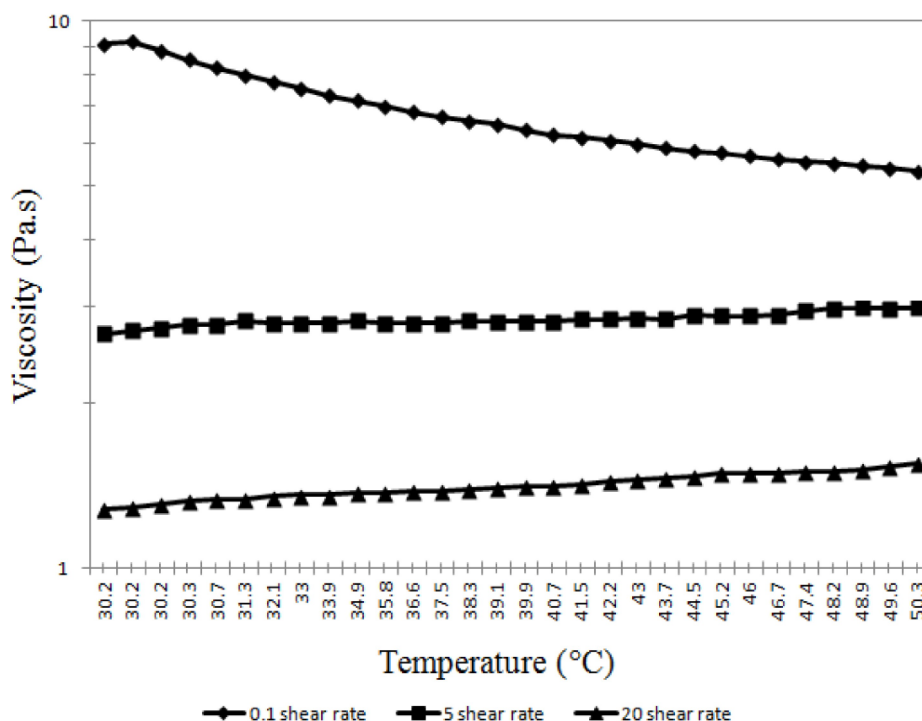


Figure 2 : Plot of viscosity (Pa.s) vs temperature (°C) at different shear rates

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ment in the water solution. However, the increase in temperature loosens the guar gum molecular arrangement and the intermolecular forces of attraction between guar gum/water and guar gum/guar gum, leading to decrease in viscosity with increase in temperature. More and more rupturing of guar gum molecular chains happen at higher shear rates. Thus, the rupturing of molecules will be higher at shear rate of 20 s^{-1} than that at 5 s^{-1} . This rupturing was high enough, for the temperature to have no effect on the viscosity.

Secondly, viscosity decreased with increase in shear rate at same temperature. More the shear rate, more is the rupturing of the polymer chain arrangement happening in guar gum. Decrease in viscosity is drastic with increase in shear rate.

Effect of time on viscosity of guar gum at constant shear rate

Figure 3 plots the effect of time on the viscosity of guar gum at different shear rates. Viscosity decreased with increase in shear rate. However, viscosity remained nearly constant at a particular shear rate for various time.

Thus, it can be said that, time has no effect in affecting the viscosity of guar gum. Nevertheless, shear rate has a significant role in affecting the viscosity. Decrease in viscosity is appreciable at a particular time.

Higher the shear rate, higher is the rupturing of the polymeric chain arrangements. So, viscosity at shear rate of 20 is lowest and increased with decrease in shear rate.

Frequency sweep at varied temperature

Figure 4 is a plot, showing the effect of angular frequency on the storage modulus, loss modulus and damping factor of guar gum solution at different temperature. Storage and Loss modulus increased with increase in angular frequency and temperature. Loss and storage modulus at 30 and 40°C is nearly same, but appreciably improves at 50°C . Damping factor is a ratio of loss modulus to storage modulus. Thus, higher the damping factor more viscous the material is; whereas, lower the damping factor more elastic the material is.

Damping factor decreased with increase in temperature and angular frequency. Thus, the guar gum solution becomes more elastic at higher temperature and angular frequency. Guar gum being a very high molecular weight material, its chain molecular chains remain entangled with each other. The level of entanglement increased with increase in temperature, may be due to the kinetic movement induced at increased temperature. However, damping factor decreased with increase angular frequency, due to the resistance offered by the guar gum polymer chains to the rotating spindle.

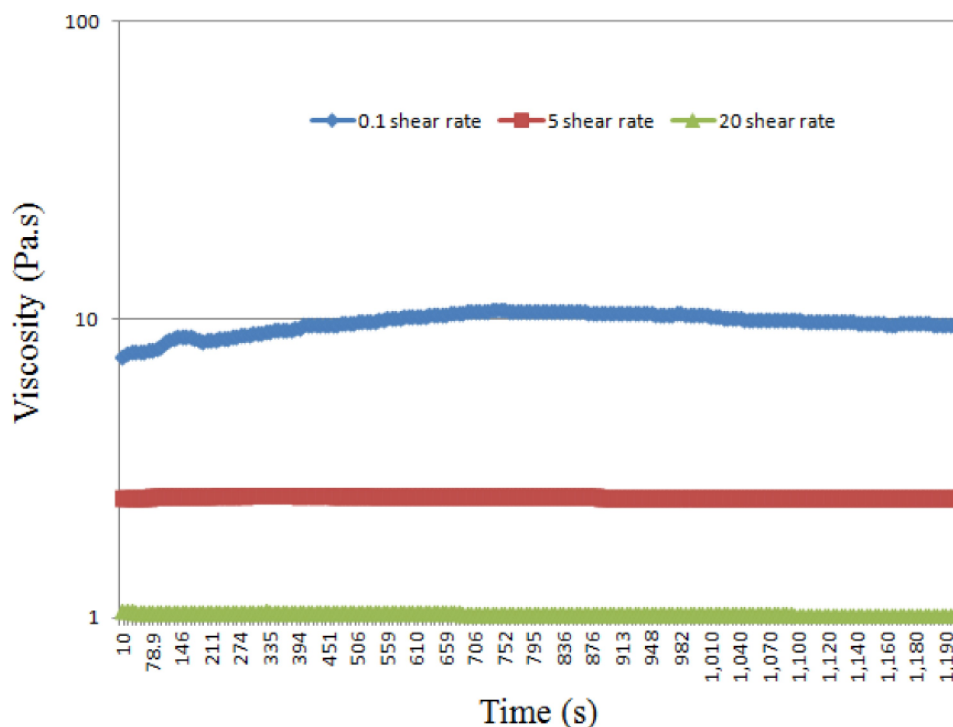


Figure 3 : Plot of viscosity (Pa.s) vs time (s) at different shear rates

Effect of temperature on damping factor

Figure 5 plots the effect of temperature on the damping factor of guar gum solution at three different angular

frequencies. Damping factor remained constant with increase in temperature for a particular angular frequency. Whereas, damping factor decreased with increase in

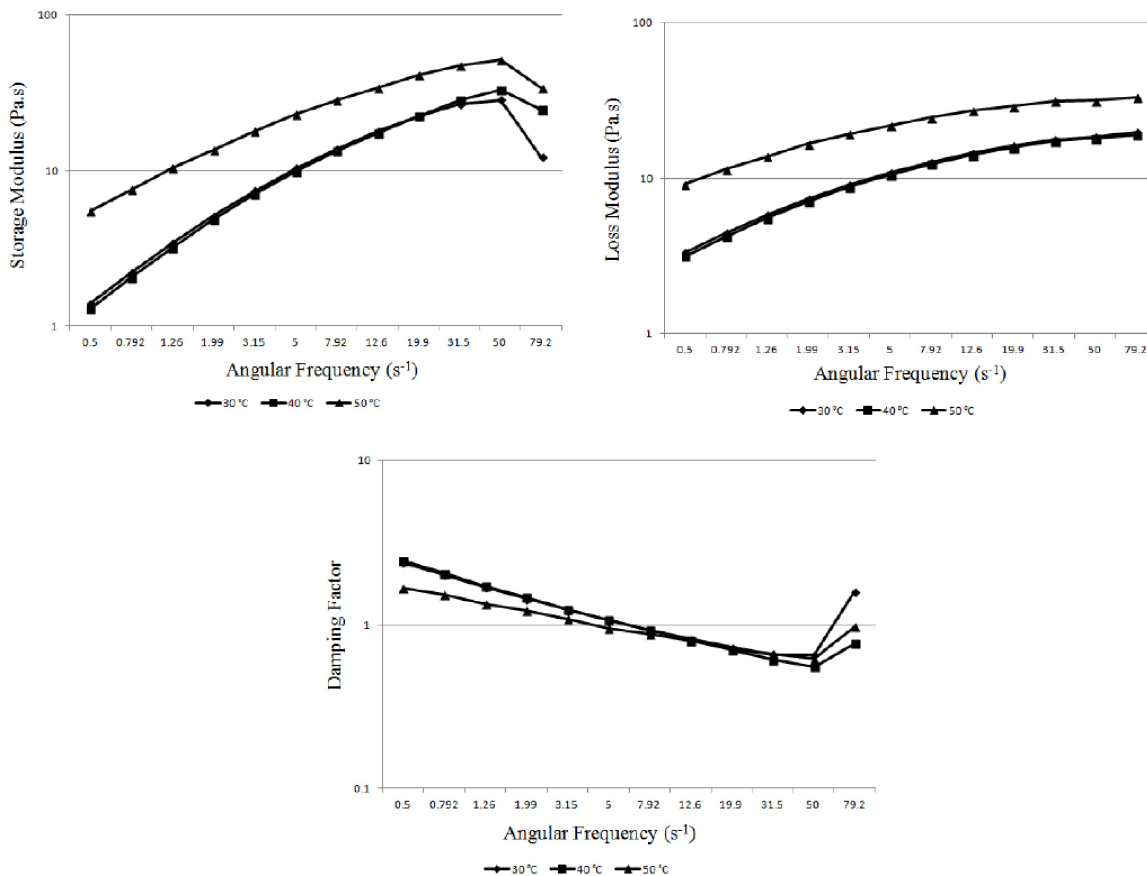


Figure 4 : Plot of storage modulus vs angular frequency, loss modulus vs angular frequency and damping factor vs angular frequency

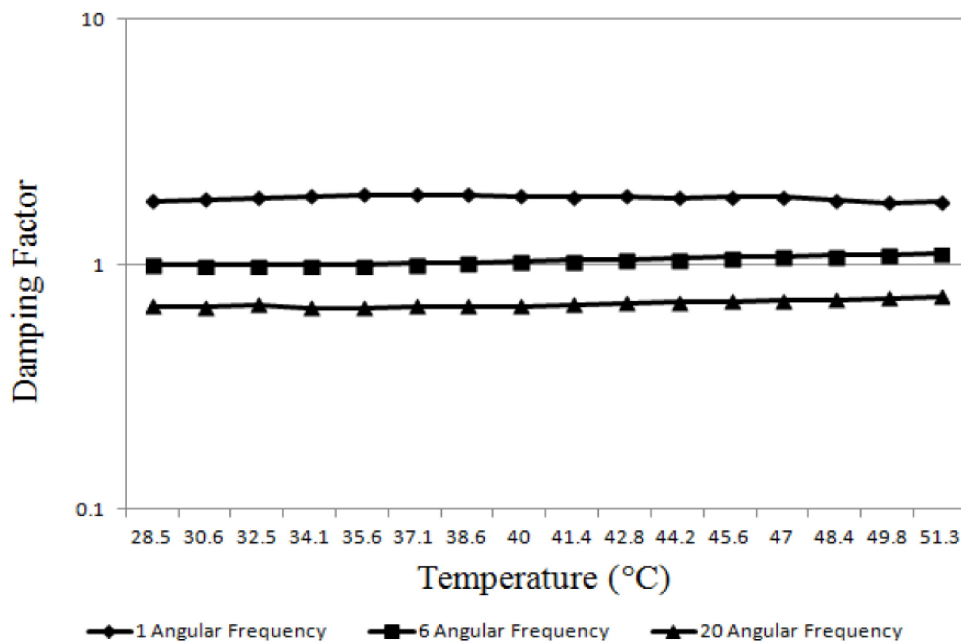


Figure 5 : Plot of damping factor vs temperature

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angular frequency for a particular temperature.

Thus, temperature has no effect on the damping factor of guar gum solution. However, the increase of damping factor with angular is mainly due to the resistance caused by the entangled guar gum polymer chains, resisting the movement of polymer chains to the rotating rheometer spindle. Thus, guar gum behaves more as elastic material at higher angular frequencies.

CONCLUSION

1 % guar gum solution in water was subjected to various rheological testings. Guar gum solution showed shear thinning behavior with decrease in viscosity with temperature. Temperature had no effect on the viscosity as well as the damping factor of guar gum solution. However, guar gum behaved more as an elastic material at higher angular frequencies, due to the resistance caused by the entangled polymer chains to the rotating rheometer spindle.

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