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Rheological Characteristics of Sudanese *Acacia senegal* Gum

Ali A. Rabah

Department of Chemical Engineering, Faculty of Engineering, University of Khartoum
Khartoum, Sudan (E-mail: rabahssr@uofk.edu)

Abstract: The objective of this study is to provide rheological data of *Acacia senegal* (*A. senegal*) gum of Kordofan origin. The density of *A. senegal* gum at room temperature is found to be higher than that of water only at higher concentration (>5 g/L). The density is also found to be strong function of temperature. At medium temperature >45 °C becomes lower than that of water even at low concentration (<2.5 g/L). The viscosity is found to be shear rate independent indicating Newtonian behavior. At low concentration *A. senegal* gum viscosity varies linearly with concentration and at high concentration (>10 g/L) varies exponentially. The study also provides review information on physicochemical and mineralogical characteristics as well as the structure of *A. senegal* gum.

Keywords: *A. Senegal* gum; Rheology , viscosity, density

1. INTRODUCTION

A. senegal gum has many applications including confectionery, beverages, flavour encapsulation, water hardness improves among other. In the confectionery industry, it is used in a variety of products including gums, pastilles, marshmallows and toffees. *A. senegal* gum is stable in acid conditions and is widely used as an emulsifier in the production of concentrated citrus and cola flavour oils for application in soft drinks. It is able to inhibit flocculation and coalescence of the oil droplets over several months and furthermore the emulsions remain stable for up to a year when diluted up to ~500 times with sweetened carbonated water prior to bottling. Microencapsulation is commonly used to transform food flavours from volatile liquids to flowable powders that can be readily incorporated into dry food products such as soups and dessert mixes. The process also renders the flavour stable to oxidation [1]. Despite its many applications, *A. senegal* gum is not yet fully understood. Research on physical, chemical, mineralogical and rheological characteristics as well as on its structure is yet to be saturated [2].

Structure: The structure of *A. senegal* gum is of concern to many investigators. Typical analytical data for *A. senegal* gums are given in Table 3. It consists of rhamnose and glucuronic acid contents and higher arabinose and 4-O-methyl glucuronic acid contents. *A. senegal* gums have also high molecular weight [1].

Physicochemical characteristics: Table 2 shows physicochemical properties of *A. senegal* gum of different

origins. *A. senegal* gum readily dissolves in water to give clear solutions ranging in color from very pale yellow to orange - brown and with a pH of ~4.5. It has specific rotation of about -30 [1].

Mineralogy: Recently *A. senegal* gum is used to enhance hardness of bottled water [2]. Hence the content of the mineral salts are very important. However, there is little information of the salts content of *A. senegal* gum in the literature. Table 3 shows mineral content of various gums of Ethiopian and Tanzanian origins.

Rheological properties: Little information is available about the rheological characteristics of *A. senegal* gum. Figure 1 shows the viscosity of *A. senegal* in comparison with viscosity of xanthan gum and sodium carboxymethylcellulose. It is seen that even 30% of the *A. senegal* gum solutions have a lower viscosity than xanthan gum and sodium carboxymethylcellulose at low shear rates. In addition, while *A. senegal* gum is Newtonian in behaviour with viscosity being shear rate independent, both xanthan gum and sodium carboxymethyl cellulose display non-Newtonian shear thinning characteristics [1].

2. MATERIALS AND METHODS

The materials used in this work include mechanical powder of *A. senegal* gum and demineralized water. Commercially available mechanical powder of *A. Senegal* gum was supplied by Sudanese Gum Arabic Company. The physicochemical properties of supplied *A. Senegal* gum are given in Table 2.

Table 1. Characteristics of gum from *A. senegal* and *A. seyal*

Property/composition	<i>A. senegal</i>	<i>A. seyal</i>
% galactose	44	38
% arabinose	27	46
% rhamnose	13	4
% glucuronic acid	14.5	6.5
4-O-methyl glucuronic acid	1.5	5.5
% nitrogen	0.36	0.15
Specific rotation/degrees	-30	+51
Average molecular weight (MW)	500-600	800K- 1.5M

Table 2. Physicochemical properties of *A. Senegal* gum

Property	Sudan (Rabah <i>et al.</i> , [3])	Tanzania (Mhinzi and Mrosso, [4])	Kenya (Lelon <i>et al.</i> , [5])	Ethiopia (Yebeyena, <i>et al.</i> , [6])
Moisture content %	9.5	13.8	13	15
Ash content %	3.5	4.2	2.0	3.56
pH on 25% solution	4.33	na	na	4.4
Specific rotation	-29.79	-24.6	na	-32.5
Nitrogen content%	0.28	4.4	na	0.35
Protein content %	1.83	2.9	na	2.31

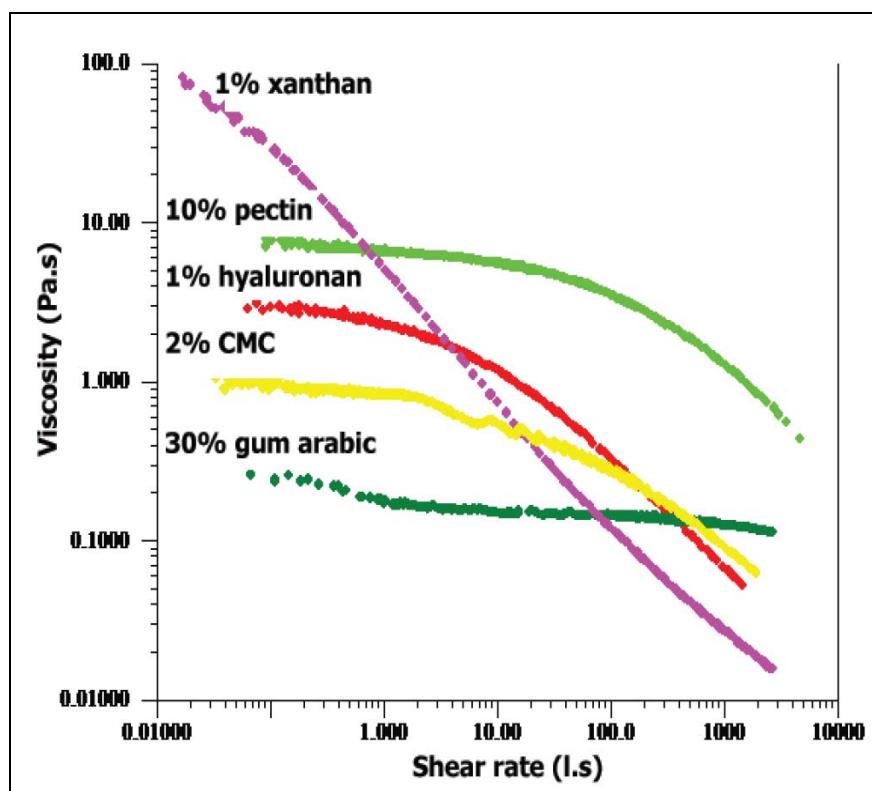


Fig. 1. Viscosity shear rate profiles of *A. senegal* gum solution
(Al-Assaf and Phillips, [7])

Demineralized water is prepared at Chemical Engineering Laboratory by double distillation.

The viscosity was measured using DV III Ultra Rheometer with an accuracy of $\pm 1.0\%$ of range and repeatability of $\pm 0.2\%$. The density was measured in accordance with ASTM D4052. Both density and viscosity were measured in the Central Petroleum Laboratory (CPL), Ministry of Petroleum, Sudan.

3. RESULTS AND DISCUSSION

3.1 Density

The density of *A. senegal* gum solution is measured at different concentration at room temperature of $25\text{ }^{\circ}\text{C}$ (cf. Fig. 2). The density is also measured at constant concentration for a wide range of temperature $15\text{ }^{\circ}\text{C}$ to $60\text{ }^{\circ}\text{C}$ (see Fig. 3). Fig. 2 is plotted in a semi-log diagram to magnify the profiles. The density is higher than that of water only at high gum concentration ($>10\%$ gum). The highly branched structure of *A. senegal* gum gives rise to compact molecules with a relatively small hydrodynamic volume. As a consequence, gum solutions become dense at high concentrations. This may justify the results.

Fig. 3 shows the dependency of *A. senegal* gum solution on temperature. The density profile assumes logical trend; it

decreases with temperature. This is due to the fact that the molecules are loose packed hence occupying large volume as temperature increases. The result is also compared with that of pure water at the same temperature. For water, the density assumes similar trend. However, at temperature higher than $35\text{ }^{\circ}\text{C}$ the density of *A. senegal* gum solution is lower than that of water.

3.2 Viscosity

Fig. 4 shows the viscosity of *A. senegal* gum solution at different concentrations at a temperature of $40\text{ }^{\circ}\text{C}$. The data are plotted in semi-log diagram for the same reason mentioned in relation to Figure 1. It can be seen that the viscosity increases with increasing concentration. Again, the highly branched structure of *A. senegal* gum gives rise to compact molecules with a relatively small hydrodynamic volume. As a consequence, gum solutions become viscous only at high concentrations. At low concentration *A. senegal* gum viscosity varies linearly. At high concentration $> 20\text{ w/v}$ it varies exponentially. Similar results are reported in the Handbook of hydrocolloids. In addition, *A. senegal* gum is Newtonian in behavior with viscosity being shear rate independent as can be seen in Figure 1. Similar trend to that shown in Fig 4 is found by Williams and Phillips [1] as shown in Fig. 5.

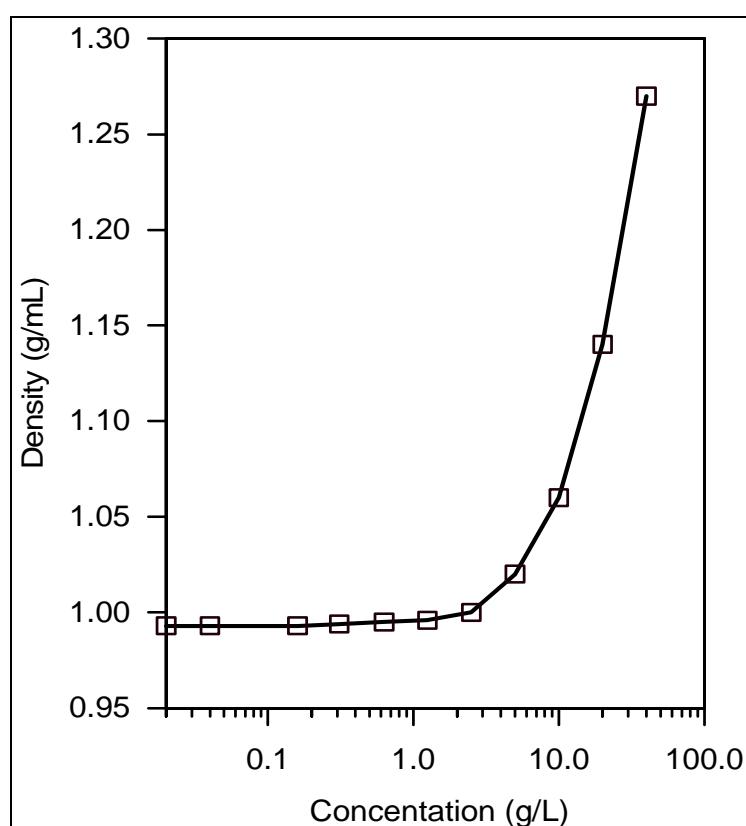


Fig. 2. Variation of density with concentration

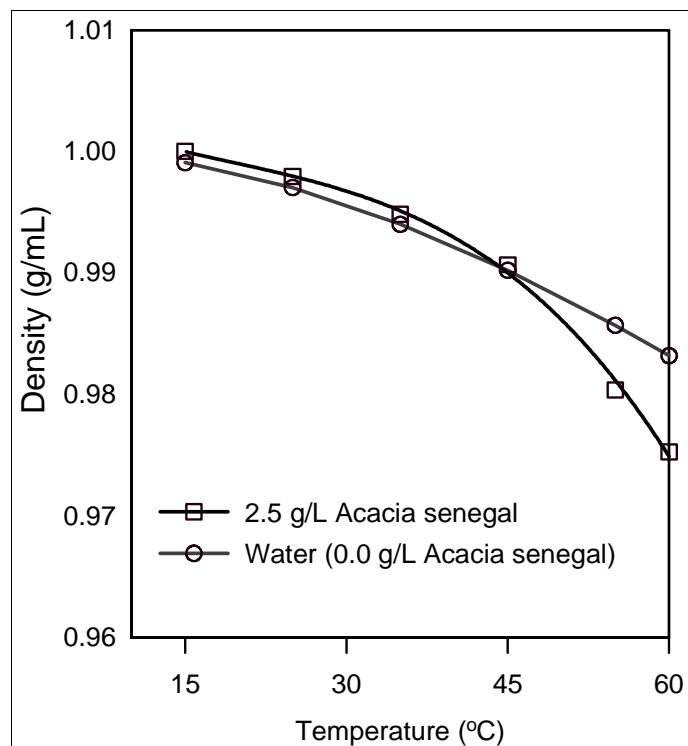


Fig. 3. Dependency of density on temperature

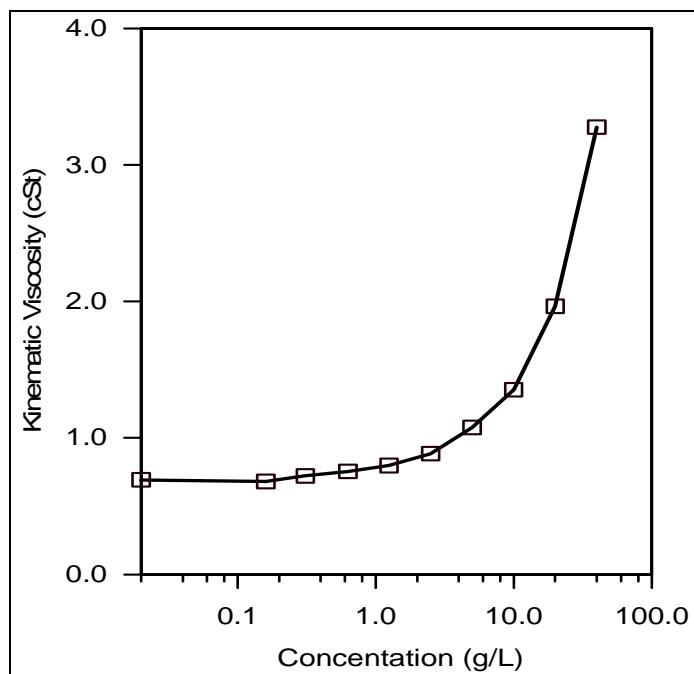


Fig. 4. Variation of viscosity with concentration

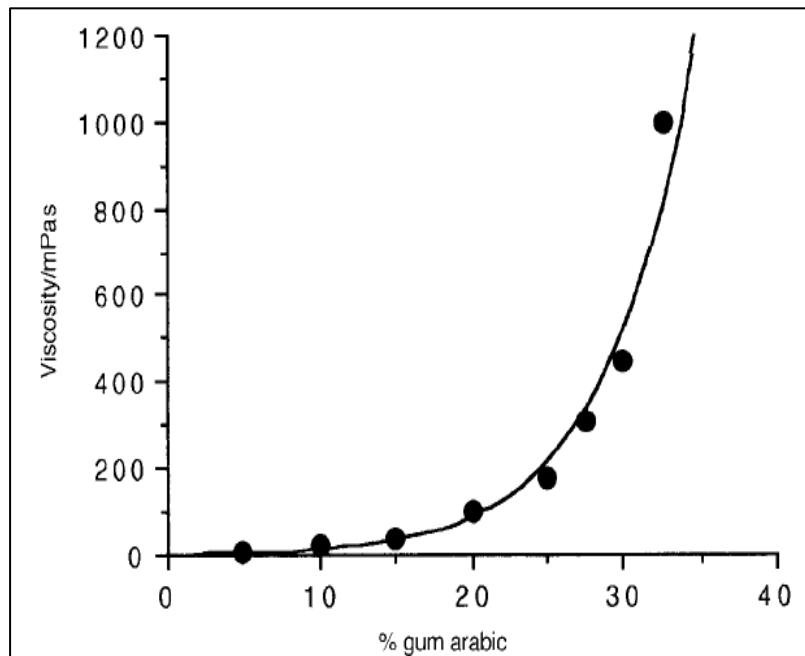


Fig. 5. Viscosity vs concentration (Williams and Phillips, [1])

4. CONCULSIONS

The work presented the result of experimental investigation on rheological characteristics of *A. senegal* gum. It provides valuable information on density and viscosity of *A. senegal*. The resulted confirmed that *A. senegal* gum has a Newtonian behaviors and the viscosity increases exponentially at high concentration. The work also complied physicochemical properties and minerals content of *A. senegal* gum from Sudan, Kenya, Ethiopia and Tanzania

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