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# PHYSICOCHEMICAL AND RHEOLOGICAL STUDIES OF *Irvingia gabonensis* GUM EXUDATES AS SUBSTITUTE TO GUM ARABIC

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*ABSTRACT*
***Irvingia gabonensis (Aubry-Lecomte ex O'Rorke) Baill is a plant found in North Central and North Eastern Nigeria. The plant is used for various purposes such as food and medicine. Physicochemical and rheological studies were carried out on the plant gum exudates. Using standard procedures and the results were compared to that of Acacia senegal (L.) gum exudates. From the results of the physicochemical analysis of Irvingia gabonensis gum exudates it was found out that it has low solubility and high total dissolved solids values in water when compared to Acacia Senegal, odourless, tasteless and with pH values of 5.42. The viscosity value of the gum exudates were found to decrease with increase in temperature while increases in concentration of the gum exudates were found to increase the viscosity of the gums. And addition of electrolytes solution such as KCl, KBr and $AlCl_3$ were found to increase the viscosity of the IG and AS gums solution. The results for the different analysis carried out gives an insight into the possibility of using the plant gum as a replacement for Acacia Senegal gum in applications such as food additive, pharmacological and industrial.***
***Keywords: Irvingia gabonensis (IG); gum exudates; electrolytes; rheological studies; Acacia Senegal (AS).***

## INTRODUCTION

A gum in general, is any water-soluble or water-swellable polysaccharide that is extractable from marine and land plants, or from microorganisms that possess the ability to contribute viscosity or gelling ability to their dispersions (Abu Baker *et al.,* 2007). The most fundamental property of a gum therefore is its water solubility and high viscosity in aqueous dispersions. Among the advantages of natural gums over their synthetic counterparts are their biocompatibility, low cost, low toxicity (eco-friendliness) and relative widespread availability (Odeku, 2005; Emeje *et al.,* 2009; Nep and Conway, 2010; Ogaji and Okafor, 2011).

Plant gums are organic substances obtained as an exudation from fruits, trunk or branches of the trees spontaneously or after mechanical injury of the plant by incision of the bark or after the removal of the branch or after invasion by bacteria or fungi (Ahmed *et al.*, 2009). Gums are complex polysaccharides which consist of high molecular weight polymeric compounds composed mainly of carbon, hydrogen, oxygen and nitrogen. They are capable of displaying colloidal properties in an appropriate solvent or swelling agent. According to Ahmad *et al.* (1994), most plant gums are polyelectrolytes, which is a class of polymers that bears a large number of ionizable groups on the main chain. Gums have numerous applications in several industries. For example, *Albizia zygia* and some *Albizia lebbeck* gums have been found to be useful as natural emulsifiers for food and pharmaceuticals (Mhinzi, 2002). According to de Paula et al. (2001), *Albizia lebbeck* gum exudate is also used as a substitute for Arabic gum in the metallurgical industries. Guar and some other gums have a number of applications in the mining and mineral processing industry (Ma and Pawlik, 2007). *Irvingia gabonensis*(Aubry-Lecomte ex O'Rorke) Baill, is a specie of tree that grow in West Africa. It produces a fruit that is similar to mangoes. People use the flesh and seeds of this fruit to make food and medicines. This fruit is very high in fiber, protein, and healthy fats (FAO 1993-2007).

The aim of the study is to determine the physicochemical and rheological properties of the plant gums from *Irvingia gabonensis* and compare the properties of the plant gums with Gum Arabic *(Acacia senegal)* which is one of the most commercially used plant gum.

## MATERIALS AND METHODS

Crude *Irvingia gabonensis* gum was obtained as dried exudates from their parent trees. The gum was collected from the plant species by tapping (Smith and Montgomery, 1959).

The procedure adapted for the purification of the gum was that of Femi – Oyewo *et al.*, (2004). The pH and conductivity were determined according to the method of ASTM D3838-80.

The solubility of the gum was determined in cold, hot distilled water and ethanol. One gram (1.0g) of the gum sample was added to 50ml each of the above mentioned solvents and left overnight. 25ml of the clear supernatants were taken in small pre-weighted evaporating dishes and heated to dryness over a digital thermostatic water bath. The weights of the residue with reference to the volume of the solutions were determined using a digital top loading balance (Model.XP-3000) and expressed as the percentage solubility of the gums in the solvents (Carter 2005).

Density measurements were carried out at $25^0$C using $25cm^3$ density bottle. For the gum sample, a density of the aqueous solution was determined. Clean, dry density bottle was weighed (M0) on a digital top loading balance. The bottle was then filled with distilled water and weighed again (M1). Another weighing (M2) was done with the gum solution replacing distilled water in the density bottle. Relative density of gum solution was evaluated as:

$$RD = \frac{M_2 - M_o}{M_1 - M_o} \quad (1)$$

A Cannon Ubbelohde capillary viscometer (Cannon Instruments, model I-71) was used. The gum solution was prepared by dispersing 1.0g of the gum sample in 100 ml of distilled water at room temperature. Twelve milliter (12ml) of the prepared sample was transferred into the viscometer. The viscometer was immersed in a thermostated viscometer bath, calibrated using a thermometer with a precision of 0.01 K, to equilibrate for 10 minutes at 30 $^0$C. After equilibration, the sample was pumped into the bulb and allowed to flow past the lower mark on the viscometer under the influence gravitational force. The time of flow of the sample from the upper through the lower mark was noted and recorded in seconds. Triplicate measurements were made and the average values reported. Serial dilution was performed *in situ* to obtain other concentrations (0.8, 0.6, 0.4 and 0.2%w/v). The relative viscosity was calculated using the equation:

$$\eta_{(\eta) relative viscosity} = \frac{T - T_o}{T_o} \quad (2)$$

Where $T$ is the flow time of the gum mucilage in seconds and $T_o$ is the flow time of solvent (water) in seconds.

$[\eta]$ is defined by the following relationships:

$$\text{Relative viscosity: } \eta_{rel} = \frac{\eta_{solution}}{\eta_{solvent}} \quad (3)$$

$$\text{Specific viscosity: } \eta_{sp} = \eta_{rel} - 1 \quad (4)$$

$$\text{Intrinsic/reduce viscosity: } \eta_{red} = \frac{\eta_{sp}}{C} \quad (5)$$

**Effects of Temperature, Concentration and Added Electrolytes on Viscosities of Gums**

The viscometer was used as described above. One percent (1% w/v) concentrations of each of the gums were prepared and their viscosities at temperature range 30 - 70 $^0$C were determined. Also, another 1 % w/v concentration of the gums at different concentrations of KCl, $AlCl_3$, KBr i.e., 0.2, 0.4, 0.6, 0.8 and 1.0M of the electrolytes solutions were prepared. Viscosity values of the gums at different concentrations of electrolytes were measured.

## RESULTS AND DISCUSSION

**Physicochemical Properties**

The result of physicochemical parameters of *irviginia gabonensis (IG)* and *Acacia Senegal (AS)* gum exudates are shown in Fig. 1.0 and Table 1.0 The AS gum was found with higher solubility values (AS = 9.8 and IG = 6.6) in water compare to IG gum, while IG gum has the highest UV maximum absorption and density values.

The results obtained revealed that the colour of IG and AS gums is brownish and yellow respectively. Also, the gums displayed odourless and tasteless characteristics. Upon purification, the yields for the gums were relatively high ranging from 86.60 % for IG gum to 90.50 % for AS gum. At the measured room temperature (30 $^0$C) the pH of IG and AS gums was 5.42 and 5.01 respectively. This indicates that the gums are acidic and the degree of acidity tends to vary from one gum to another. All the gums studied were found to be soluble in water but insoluble in ethanol. This also indicates that the gums are ionic. As a rule, ionic compounds are soluble in water and other solvents that have high dielectric constant. The solubility of IG and AS gums in water was found to increase with increase in temperature. The observed increase in solubility with temperature indicate that the heat given off in dissolving the gum is less than the heat required to break the gum apart. The net dissolution reaction is endothermic (energy required). Therefore, addition of more heat facilitated the dissolution of the gum by providing energy to break bonds within the gums.

On the other hand, chloroform and acetone are non-polar solvents and as expected, non-polar compounds are soluble in non-polar solvent and vice versa. It has been found that the solubility of some ionic compounds vary in this manner the measured conductivities of IG and AS gums (123.6 and185 μS/cm respectively) were relatively high and comparable with those of ionic compounds (Rouxel, 2011). However, the two gums were found to exhibit low salinity values indicating that the conductivity of the gums may not be primarily due to the presence of ions but due to movement of charges within the colloidal system (Zadeh *et al.*, 2007).

Measured values of turbidity for IG and AS gums were 79 and 25 FAU respectively. These results indicate that the ability of the studied gums to scatter light follows the order AS>IG. It is interesting to note that AS gum is slightly turbid because of weak light scattering while IG is highly turbid because of strong light scattering. Turbidity is related to light scattering according to Dror *et al.*, (2006) and according to Pablyana *et al.*, (2007), increasing values of turbidity implies higher amount of insoluble contents in the polysaccharides while Yadav *et al.*, (2008) also related turbidity as a property that increases with increasing emulsifying property of a polymer. The density of the gums indicates that the aggregate of particles or mass per volume of IG gum is higher than that of the AS gum. with temperature due to changes in properties and structure of liquid water. An increase in temperature can increase the degree of solute-solvent interaction resulting in an increase in solubility.

The high λmax noticed in the gums may be as a result of high degree of conjugation which absorb light in the UV or visible regions of the electromagnetic spectrum. λmax of IG gum is 366nm that of AS gum is 200nm. The increase in IG gum which maybe as a result of the presence of high percentage composition of conjugated organic compounds, it may also be as the result of interaction of polymeric substance present in the IG gum, thereby increasing its ability to absorb more UV electromagnetic spectrum.

**Effects of Temperature, Concentration and Addition of Electrolyte on the Viscosity of the Gum Solutions**

Effects of temperature on the viscosity of the gums are shown in Figs. 1.0 and 2.0. The viscosity values were found to decrease with increase in temperature. Increases in concentration of the gums were also found to increase the viscosity of the gums as shown in Figs. 3.0, 4.0 and 5.0. Addition of electrolytes such as KCl, KBr and $AlCl_3$ were found to increase the viscosity of the gums solution as shown in Figs. 6.0, 7.0 and 8.0.

**Table 1.0.Physicochemical parameters of *Irviginia gabonensis*(IG)and *Acacia Senegal*(AS) gum**

| Physicochemical parameters | *Irvingia gabonensis*(IG) Gum | *Acacia senegal*(AS )Gum |
|---|---|---|
| Colour | Brownish | Yellow |
| Odour | Odourless | Odourless |
| Taste | Tasteless | Tasteless |
| Solubility @ 30°C , N=3 | 6.6±0.1 | 9.8±0.0 |
| (a) Water (%) | | |
| (b) Ethanol (%) | 0 | 0 |
| pH@27°C, N=3 | 5.42±0.01 | 5.01±0.01 |
| UV Max. Absorption (nm) , N=3 | 366 | 200 |
| Turbidity (FAU) ,N=3 | 79±1 | 25±0 |
| Conductivity (μs/cm) , N=3 | 123.6±1.4 | 185.0±0.0 |
| Salinity (psu) , N=3 | 0.2±0.1 | 0.1±0.0 |
| Density , N=3 | 1.36±0.00 | 1.35±0.00 |
| Total dissolve solid (mg/l) , N=3 | 92.0±0.2 | 87.0±0.1 |

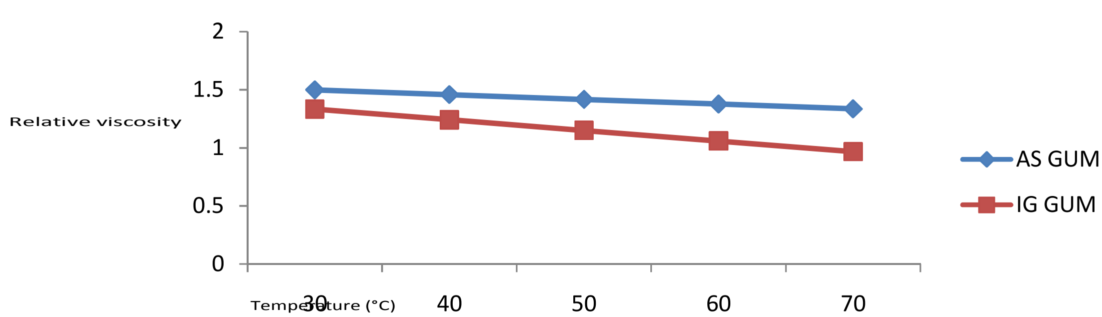


**Fig. 1: Effect of temperature on relative viscosity of the gums**

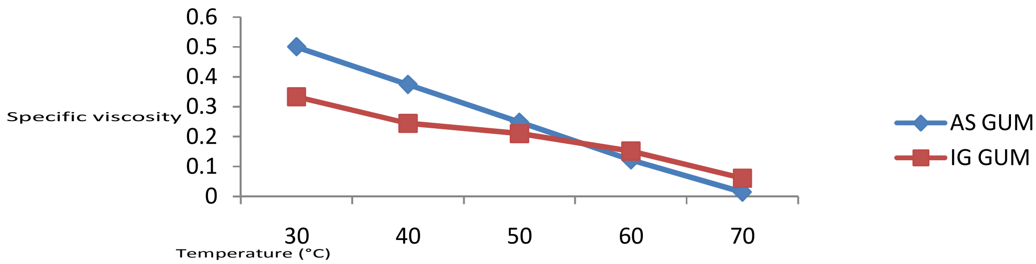


**Fig. 2: Effect of temperature on specific viscosity of the gums**

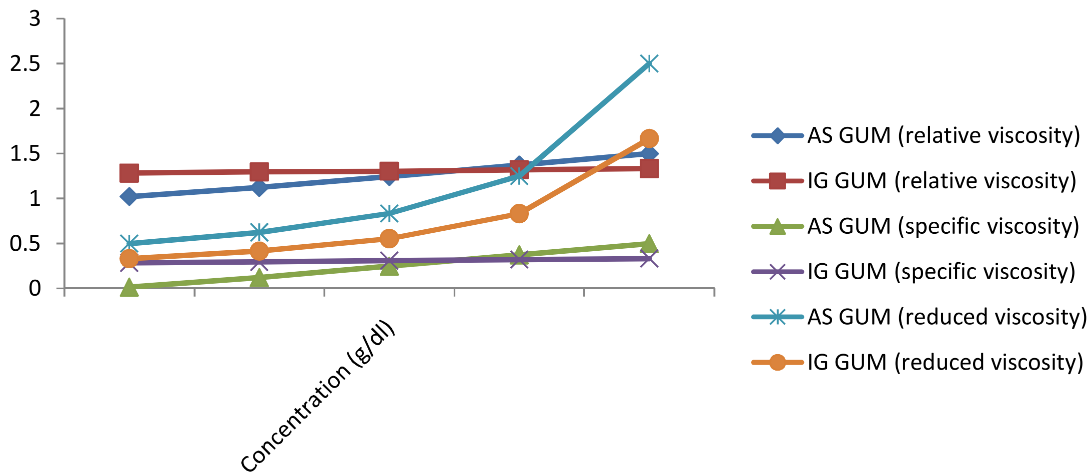


**Fig. 3: Effect of concentration on the viscosity of the gum solutions.**

**Effects of Increase in Temperature and Concentration on Viscosity**

Figs. 1 and 2 present plots for the variation of relative and specific viscosity with variable temperature. It is evident from the Figs. 1 and 2 that the relative and specific viscosity of the gums tends to decreases with increase in temperature of the gum but it increases with increase in concentration of the gum (Figs. 3 and 40). The trend observed for the gums can be explained as follows. At low temperature values, the electrostatic repulsions between the gum particles are low but at higher temperature the repulsive force is high thereby reducing the viscosity. But on the other hand the increase in viscosity due to increase in concentration of the gums is as the result of increase in association but at lower concentration there is decrease in association due to possible formation of hydrogen bonds, Van der Waals and other weak forces. Therefore increase in concentration of the pure gums led to an increase in their specific viscosity, with *Acacia senegal* gum (AS gum) having the highest value of specific viscosity value and *Irvingia gabonensis* gum (IG gum) being the least.

**Effects of Added Electrolytes on the Viscosity**

Exudate gums are acid polysaccharides containing various metal ions as neutralized cations. It has been found that due to their metal content, exudate gums behave as polyelectrolyte (de Paula *et al.*, 2001). Therefore, the solution viscosity of the gums can be affected by the addition of other electrolytes. In this study, effects of KCl, KBr and $AlCl_3$ on the viscosity of IG, and AS gums were investigated. Figs. 6.0, 7.0 and 8.0 show the variation of viscosity in IG and AS gums with concentrations in the presence of 0.1 M of KCl, KBr and $AlCl_3$. The electrolytes (KCl, KBr and $AlCl_3$) were found to increase the viscosities of IG and AS gums such that the magnitude of increase tend to increase with increase in the charge of the ions (i.e. $Al^{3+}>K^{+}$). The order observed for the effect of $K^{+}$ and $Al^{3+}$ on viscosity of IG and AS gums can be explained as follows. The KCl and $AlCl_3$ increases the viscosity of IG and AS gums because the electrolytes (KCl and $AlCl_3$) has the steric capability of gelling the gums compared to KBr. This capability is less or absent in KBr hence, KCl exhibited the greatest potential to increase the viscosity of the gums, followed by $AlCl_3$.

The decrease found in AS gums in KBr according to de Paula *et al*. (2001) can be attributed to existence of less intermolecular interaction due to the screening charges and contraction of the macromolecule in the presence of counter ion. It has been found that aluminium has a tendency of establishing strong interaction with macromolecules through intermolecular cross-linking effect. On the other hand, the strength of intermolecular cross-linking effect is lower in potassium ($K^+$) than in aluminium ($Al^{3+}$). This explains the order observed for decrease in viscosity in terms of AS gums. Ahmad *et al*. (1994) found that in dilute solution, the turbidity of dilute polyelectrolyte increases with increase in the charge of the ions present. In this work, the variation of the viscosities of the studied gums with increasing charge can therefore be attributed to their effect on turbidity. It is also significant to state that the affinity between each of the studied gums and their counter ions depends on the ratio (charge/ionic ratio). Generally, ions with higher charge will have a stronger affinity for the molecular chain of the gum. The charge to ionic radius ratio of $K^+$ and $Al^{3+}$ are 0.66 and 4.41 respectively hence the expected order for the interaction of the studied gums with metal ions is $Al^{3+}>K^+$, which is in agreement with the findings of this study.

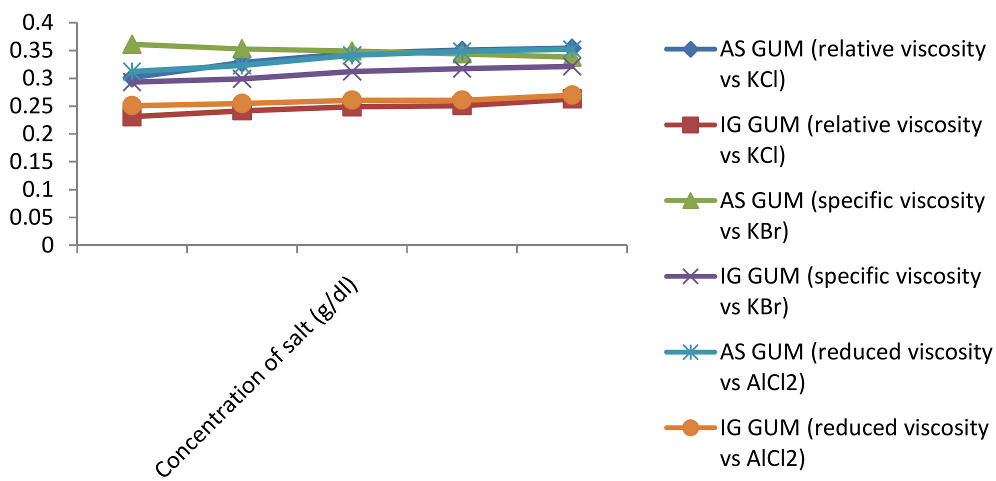


**Fig. 3: Effect of Electrolytes on the viscosities of the gums solution**

In all the studied gums, it was found that KCl and $AlCl_3$ increased the viscosity of the gum solution by their tendency to form a porous framework, they have the ability to trap many organic compounds in its so-called clathrates (the organic guest) molecules are held in channels formed by interpenetrating helices.

## CONCLUSION

*Irvingia gabonensis* gum occurs as brownish in colour. The gum mucilage has a bland taste, odourless and mild acidic with a pH of 5.4 at 300 K. It is soluble in water and practically insoluble in ethanol, acetone and chloroform. The effects of electrolytes on the viscosity of the *Irvingia gabonensis* gum solutions are found to be in agreement with what is found in *Acacia Senegal* gum, hence it can be recommended for used as food additive, pharmaceutical and industrial applications,

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