STUDIES ON SOME PHYSICOCHEMICAL PROPERTIES OF THE PLANT GUM EXUDATES OF Acacia senegal (DAKWARA), Acacia sieberiana (FARAR KAYA) and Acacia nilotica (BAGARUWA)

A.K. Yusuf
Department of Basic and Applied Sciences, Hassan Usman Katsina Polytechnic P.M.B. 2052, Katsina, Nigeria
E-mail: akyusufknk@yahoo.com

Abstract
The physicochemical properties of gum exudates from three Acacia tree species (A. senegal, A. sieberiana and A. nilotica) in Batagarawa, Katsina State, were determined and compared. Data generated from the study confirm that there are a number of physicochemical differences between the gum exudates. Physicochemical properties vary among the three samples studied within the following ranges: moisture (13.40-16.20%); water solubility at 30°C (38-45%); pH of 25% solution (4.50-5.00); relative density of 20% solution (30°C) (1.23-1.32); melting temperature (289-320°C); relative viscosity of 1% solution (20.18-24.80); total ash (3.30-3.54%); nitrogen (0.38-0.42%); protein (2.51-2.77%) and total soluble fibre (77.99-80.41%). Analysis of all the samples showed no tannin content. Determined cationic composition of the gum samples shows calcium (Ca), magnesium (Mg), iron (Fe), sodium (Na) and potassium (K) as the predominant minerals. Copper (Cu), nickel (Ni), cobalt (Co), manganese (Mn), chromium (Cr), zinc (Zn) and lead (Pb) were not detected by this study. Despite the physicochemical differences among the samples studied, values of physicochemical parameters obtained compare well with those reported in previous studies on Acacia gums in many parts of the world. There is great potential for the exploitation and application of these gums industrially.

Keywords: Physicochemical properties; gum; Acacia species; Batagarawa

Introduction
Plant gums such as gum arabic (Acacia senegal), gum talha (Acacia seyal) and grewia gum (Grewia mollis) are among important agroforestry resources in Nigeria. The gums are harvested from the stems and branches of the resource gum trees as dry exudates (FAO, 1995). 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. For this reason, resins, latexes and other hydrophobic gums are not regarded as true gums. Among the advantages of natural gums over their synthetic counterparts are their biocompatibility, low cost, low toxicity (ecofriendliness) and relative widespread availability (Odeku, 2005; Emeje et al., 2009; Nep and Conway, 2010; Ogaji and Okafor, 2011).

Plant gums are biopolymeric materials composed of complex heteropolysaccharides and proteinaceous material, in addition to some mineral elements (Williams and Phillips, 2000). Gum arabic, for instance, has been shown (by hydrophobic affinity chromatography) to be made up of three major constituents namely, arabinogalactan (AG), arabinogalactan protein (AGP) and glycoprotein (GP); with AG, the highly branched polysaccharide part of the gum representing about 90% of the total gum (Randall et al., 1989; Renard et al., 2006). The complex and heterogeneous nature of plant gums in terms of their chemical composition makes it very difficult to predict their properties. Yet, their industrial application has to be based on well characterized gum samples, i.e. samples whose quality and safety of application can be assured because their physicochemical properties are well known. The physicochemical properties of a compound are the measurable physical and chemical characteristics by which the compound may interact with other systems, and these characteristics collectively determine the quality, applicability or end-use of the compound. In plant gums, these properties are directly influenced by the botanical type, age, location, nature of the growing soils and the climatic conditions around the resource gum tree (FAO, 1995; Chikamai, 1997; Idris et al., 1998; NGARA, 2005; Elnour et al., 2009). Physicochemical characterization of gums therefore is an essential step...
towards establishing their suitability for industrial application.

The use of Acacia gums (in particular) has been widely reported in industrial application notably in the food, pharmaceutical, adhesive, cosmetic, textile, paint and print industries, where they are used variously as food additives, dietary fibres, tackifiers or binders, thickeners, stabilizers, emulsifiers, suspending and surface coating agents, gelling agents etc (Yaseen et al., 2005; Al-Assaf et al., 2006; Abu Baker et al., 2007; Elnour et al., 2009). However, of the over 1100 botanically known species of Acacia distributed throughout the tropical and subtropical areas of the world, most research works on Acacia gums worldwide have been directed towards Acacia senegal and to a lesser extent, Acacia seyal. Other Acacia gums have received very little attention. The objective of this study therefore was to determine and compare the physicochemical properties of gum exudates obtained from three different Acacia tree species namely, Acacia senegal (Hausa: dakwara), Acacia sieberiana (Hausa: farar kayar) and Acacia nilotica (Hausa: bagarwa) commonly found in Katsina State of Nigeria.

Materials and Methods
Sample collection and description
The samples were obtained from three different Acacia tree species (A. senegal, A. sieberiana and A. nilotica) found naturally in surrounding forests of Batagarawa Village, Katsina State. Samples were collected from the tree barks as dry nodules or lumps. Collection of all samples was done in November/December of 2009. Each bulk sample (A, B, C) was obtained by combining the collections from randomly identified mature trees (> 10 years of age) of same species. Samples were then kept in separate (labelled) bags.

<table>
<thead>
<tr>
<th>Gum sample</th>
<th>Latin/Binomial name of gum tree</th>
<th>Hausa name</th>
<th>Sample description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Acacia senegal</td>
<td>dakwara</td>
<td>Off white-to-cream tasteless, odourless nodules</td>
</tr>
<tr>
<td>B</td>
<td>Acacia sieberiana</td>
<td>farar kayar</td>
<td>Cream-to-light yellow tasteless, odourless nodules</td>
</tr>
<tr>
<td>C</td>
<td>Acacia nilotica</td>
<td>bagarwa</td>
<td>Orange-brown tasteless, odourless lumps</td>
</tr>
</tbody>
</table>

Preparation of samples
The crude samples consisted of mixtures of large and small nodules admixed with bark and organic debris. Hand picked select gum (HPSG) method (Sabah El-Kheir et al., 2008) was used to separate the neat, quality gum from other constituents. The former was then spread out under room shade until dry. The dried samples (hard nodules) were then ground into fine powder (to pass 0.4mm mesh screen). The prepared samples were kept in tight containers and stored at room temperature until required for subsequent analysis.

Methods
Physicochemical analysis of samples under study was done in our laboratory. The samples were used unfractionated. Each analysis was repeated three times, and values reported in respect of the gum samples are actually the average of three replications.

Moisture content
Moisture content of samples was determined by drying 5g of the ground gum sample to constant mass at 80°C using a hot air oven. Dried samples were cooled in a desiccator before weighing. Moisture content was expressed as % of mass loss from the original mass.

pH
pH of 25% aqueous gum solution (w/v) was measured using a glass electrode pH meter (HANNA-209-209R).

Relative density
Density measurements were carried out at 35°C using 25cm³ density bottle. For each gum sample, densities of five different concentrations (1, 10, 20, 30 and 40% w/v) of the sample in aqueous solution were
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 (M₂-M₀)/(M₁-M₀)

**Water solubility**

Gums are uncrystallizable. The solubility of *A. senegal, A. sieberiana* and *A. nilotica* gums in water was therefore determined at room temperature (30°C) by adding 10mg of the sample to 10cm³ of distilled water and leaving the mixture overnight. 15cm³ of the clear supernatant was then taken in a small preweighed evaporating dish and heated to dryness over a water bath. The mass of the dried residue with reference to the volume of the solution was determined using a digital top loading balance and expressed as the % solubility of the gum in water (Carter, 2005).

**Melting temperature**

The melting temperature range of each gum sample was determined using a Galenkamp melting point apparatus. 1g of the ground gum was taken in a glass capillary tube and melting temperature determined repeatedly until reproducible.

**Relative viscosity**

Relative viscosity of gum samples was measured in filtered 1% aqueous solution using U-shaped viscometer (AOAC, 1990), and in four other select gum concentrations (0.2, 0.4, 0.6 and 0.8%). A flow time (seconds) of distilled water was measured by filling the viscometer tube (held at 30°C in water bath) with water and then drawn by suction to the upper mark of the viscometer. The water level was allowed to fall, passing the upper and lower marks of the U-shaped tube. Relative viscosity was evaluated thus:

Relative viscosity (30°C) = (T-T₀)/ T₀

Where; T is flow time of gum solution (sec.)

T₀ is flow time of distilled water (sec.)

**Ash content**

5g of gum sample was first heated on a burner in air to remove its smoke. Then it was burned in a furnace at 550°C. The ash content was expressed as a % ratio of the mass of the ash to the oven dry mass (Yebejen *et al.*, 2009).

**Tannin content**

0.1cm³ of aqueous FeCl₃ solution was added to 20cm³ of a 2% aqueous solution of the gum sample and mixture centrifuged. Absence of black precipitate or blackish colouration indicated the absence of tannin (FAO, 1999).

**Nitrogen and protein content**

Nitrogen was determined by semi-micro Khjeldal methods (AOAC, 1990). Protein content was calculated using the nitrogen-conversion factor of 6.6 as proposed by Anderson (1986, cited in Idris *et al.*, 1998).

**Total soluble fibre**

Total soluble fibre was obtained by subtraction of contents of moisture, ash and protein from 100, as described by Sabah El-Kheir *et al.* (2008).

**Mineral content**

Ash from gum sample was prepared and dissolved in conc. H₂SO₄. The solution was used for determination of mineral content by atomic absorption spectrophotometry, except for sodium and potassium metals, which were determined by flame photometry.

**Results and Discussion**

Table 2 depicts the physicochemical parameters obtained for the *Acacia* gum samples analyzed.

Table 2: Physicochemical properties of *A. senegal, A. sieberiana* and *A. nilotica* gum exudates

<table>
<thead>
<tr>
<th>Physicochemical parameter</th>
<th><em>A. senegal</em></th>
<th><em>A. sieberiana</em></th>
<th><em>A. nilotica</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture (%)</td>
<td>13.40</td>
<td>16.20</td>
<td>15.60</td>
</tr>
<tr>
<td>Solubility (30°C) (%)</td>
<td>40</td>
<td>45</td>
<td>38</td>
</tr>
<tr>
<td>Melting temperature (°C)</td>
<td>295-308</td>
<td>289-306</td>
<td>300-320</td>
</tr>
<tr>
<td>Relative density of 20% soln (35°C)</td>
<td>1.28</td>
<td>1.23</td>
<td>1.32</td>
</tr>
</tbody>
</table>
Table 3: Variation of relative density of gum solution with concentration

<table>
<thead>
<tr>
<th>Concentration of gum solution (% w/v)</th>
<th>Relative density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. senegal</td>
</tr>
<tr>
<td>1</td>
<td>0.64</td>
</tr>
<tr>
<td>10</td>
<td>0.89</td>
</tr>
<tr>
<td>20</td>
<td>1.28</td>
</tr>
<tr>
<td>30</td>
<td>1.44</td>
</tr>
<tr>
<td>40</td>
<td>1.73</td>
</tr>
</tbody>
</table>

Table 4: Variation of relative viscosity of gum solution with concentration

<table>
<thead>
<tr>
<th>Concentration of gum solution (% w/v)</th>
<th>Relative viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A. senegal</td>
</tr>
<tr>
<td>0.2</td>
<td>10.14</td>
</tr>
<tr>
<td>0.4</td>
<td>15.42</td>
</tr>
<tr>
<td>0.6</td>
<td>18.20</td>
</tr>
<tr>
<td>0.8</td>
<td>19.42</td>
</tr>
</tbody>
</table>

* Zinc, copper, magnesium, cobalt, nickel, chromium and lead were not detected by this study.

Physical characteristics of the gums

A. senegal, A. sieberiana and A. nilotica gum exudates collected from Batagarawa, Katsina State, were in form of tasteless and odourless nodules or lumps, with their colour varying from off-white to orange-brown (Table 1). All three gum samples were found to be water soluble at 30°C to form viscous solutions, indicating that they are natural gums of the hydrophilic colloid group. Samples were however found to be insoluble in common organic solvents (ethanol, acetone, ether, chloroform, benzene etc) and in oils, with which they form emulsions in aqueous suspension. A. sieberiana gum had the highest solubility (45%) at 30°C and A. nilotica the least (38%). The good solubility of these gums is also indicative of the absence of cross linking between polymeric chains. This is because gums having cross linked polymeric chains only swell in water, without dissolving (Remington, 2000).

Gum solution density increased with increasing solution concentration (Table 3, Fig. 1), with A. nilotica gums generally having the highest solution densities and A. sieberiana the least. Density is a measure of the degree of compact packing of macromolecules in the gums. The melting temperature range of 289-320°C (all samples) suggests that the gum samples were of good thermal stability. However, wide melting temperature range was likely due to the heterogeneous and polydisperse nature of the unfractionated gum exudates, composition-wise.
Chemical characteristics

pH measurement shows that all three gum samples were slightly acidic (pH 4.5-5.0). The pH value of 4.5 is in good agreement with reported pH values for gum arabic and other Acacia gums by several authors. The acidity of plant gums is not unexpected since many of them are known to contain salts (Ca, Mg, K, Na and Fe) of acidic polysaccharides, the acidity of which is due to uronic acids in their structures (Abu Baker et al., 2007; Ahmed et al., 2009; Elnour et al., 2009). Moisture content of the gum samples was of the range (13.4-16.2%), and compares favourably with the minimum standards (≤15%) for good quality gum arabic, according to European specification (E-414). A. sieberiana had the highest moisture content (16.2%) and A. senegal the least (13.4%).

Viscosity is a measure of the resistance of a fluid to flow. Relative viscosity of gum solution (30°C) was found to depend on gum concentration (Table 4). Viscosity of gum solution increased with increase in gum concentration. This relationship is also depicted in Fig.2.

![Fig. 1: Effect of concentration on relative density of gum solution](image1)

![Fig. 2: Effect of concentration on relative viscosity of gum solution](image2)
Fig. 2: Effect of concentration on relative viscosity of gum solution

According to Li et al. (2009), molecular association in fluids greatly influences their rheological behaviour. Increase in viscosity with concentration is probably due to increasing number of high molecular weight polymeric chains of the gums per unit volume and increased interaction between these chains in aqueous solution or dispersion. These are likely to increase cohesive density and therefore greater resistance to flow. However, higher relative viscosity values for A. nilotica gum solutions irrespective of concentration suggests the presence of higher molecular weight polymers in the gum’s chemical constitution.

Ash content (3.30-3.54%) falls within the 4% maximum limit reported by FAO (1998) for food and pharmaceutical quality gum arabic. Similarly, values for protein content obtained (2.51-2.77) fairly agree with those found by Karamalla et al. (1998). A. senegal gum had the highest protein content (2.77) and A. sieberiana the lowest. The relatively high protein content in all the gum samples is noteworthy. This is because protein content is known to have effects on the emulsifying behaviour of gum arabic, with the best emulsion capacity and stability found in gums with the highest nitrogen content (Randall et al., 1988; Dickinson, 1992).

References


Mhinzi, G.S. (2003). Intra-species variation of the properties of gum exudates from *Acacia senegal var. seagal* and *Acacia seyal var. fistula* from Tanzania BCSE 171: 67-74.


molecular weight and charges. *Biomacromolecules*, 7: 2637-2649.


