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Functional properties of *Acacia nilotica* var. *adstringens* gum

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Abstract
This paper examines the emulsion stability and rheological properties of composite sample of *A. nilotica* var. *adstringens* gum from Kordofan state.
Emulsification study of *A. nilotica* var. *adstringens* gum showed that the gum has an excellent emulsifying stability. Rheological behavior of aqueous solutions of *Acacia nioltica* var. *adstringens* gum shows that the gum solution at 25% concentration indicates a shear-thinning at lower shear rates, and a viscosity plateau (Newtonian behavior) at higher shear rates. At 50% concentration the gum solutions exhibits Newtonian flow. The dynamic rheological behavior of gum solution at 50% concentration shows that storage modulus (G′) was far less than loss modulus (G″) at all frequencies, energy of deformation is dissipated viscously and the sample exhibits liquid-like behavior.

Keywords: functional, properties, *Acacia nilotica*, kordofan

1. Introduction

Acacia adstringens is a subspecies of *A. nilotica* which is occasionally used for firewood and good quality charcoal in the Sahelian regions. It has a hard heavy heartwood, which resistants water and termites. The subspecies uses include construction work, boat-building, fencing, tool handles and art objects. It is a source of gum and tannin, the gum is locally used for making ink. The subspecies is commonly, planted as shade tree.

Many food products, in the markets, are in the emulsion state such as cheese, milk, salad dressings, sauces, beverages and coconut milk (Gonzalez 1991) [4]. An emulsion is a dispersed system that consists of two immiscible liquids (usually oil and water), with one of the liquids dispersed as small droplets in the other called continuous phase. Gums are, extensively, used as an emulsifier/stabilizer in beverage emulsion for soft drinks (Tan, 2004) [13].

The Arabinoglactan protein (AGP) fraction has been shown to be responsible for the emulsifying properties of gum arabic (Randall *et al*., 1988; Randall *et al*., 1989) [8, 9].

The function of emulsifier or stabilizer is essentially to increase the viscosity of the aqueous phase by thickening it so that it approximates or slightly exceeds that of the oil.

During the process of making a mixture of two immiscible substances, minimal contact between the oil phase and water can, initially, be achieved by the formation of small, spherical, droplets through the input of work and addition of emulsifier, facilitating the formation of these small particles by reducing interfacial tension. In fact, the aim of emulsification such as O/W is to produce a small size of droplets of the dispersed phase (oil) and the size of the droplets should not be increased during emulsion storage. This means that emulsions have to be stable for a certain period of time. Gums form a protective layer around the oil droplets that prevents droplets from aggregating, flocculating and coalescing. It also reduces the oil water interfacial tension, thereby facilitating the disruption of emulsion droplets during homogenization.

The gum from *Acacia senegal* has a functional ability to act as emulsifier that stabilizes oil-in-water emulsion (Yokoyama *et al* 1988, Randall *et al* 1988) [16, 7]. It is now known that the protein-rich high molecular mass component adsorbs preferentially onto the surface of the oil droplets. It is envisaged that the hydrophobic polypeptide chains adsorb and anchor the molecules to the surface while the carbohydrate blocks inhibit flocculation and coalescence through electrostatic and steric repulsions (NGARA, 2005). Therefore, the protein moiety affects the emulsifying behavior of gums and result in emulsion capacity and stability which is exhibition gums with high nitrogen content (Randall *et al* 1988, Dickenson 1992) [7, 9]. The emulsifying properties of gums, however, are, directly, (NGARA, 2005) [6] influenced by the botanical type, the nature of soils and the climate. In addition to the emulsifying properties of *Acacia* gums, other factors related to the emulsification process influence the properties of an emulsion (Brosel and Schubert, 1999) [1].

Rheology is the science of deformation and flow. Rheological measurements have also been considered as an analytical tool to provide fundamental insight on the structural organization of food. The degree of thickening depends on the type of gum and the level of concentration. It has been reported that gum arabic solutions show Newtonian flow behaviour in the shear rate range from $50s^{-1}$ to $100s^{-1}$, at gum concentration as low as 4%. (Mothé *et al*., 1999) [5]. In the shear rate range from 1 s^{-1} to $50s^{-1}$, the shear thinning behavior has been observed. In the gum concentration range 10 to 25%, gum solutions show a significant shear thinning behavior, as compared with that of solutions with concentration in the range 30-50 %. (Mothé *et al*., 1999) [5]. Time dependent thickening flow behavior has been observed for 3 wt% gum arabic solutions at shear rate below 1 s^{-1}. Gum arabic solutions have shown shear thinning behavior at concentrations between 3 and 32 wt%. (Sanchez *et al*., 2002) [10]. Gum solution above 30% concentration shows high solution viscosity and exhibits pseudo plasticity. (Williams *et al*., 1990) [15].

The rheological complexity of gum arabic is also evident from the increase of viscosity/elasticity with time, which has been attributed to the interfacial activity of gum arabic, gradually developing an elastic interfacial film between samples and measuring geometry. (Sanchez *et al*., 2002) [10].

2. Materials and Methods

2.1 Materials

One composite sample of *Acacia nilotica* var. *adstringens* gum collected from North Kordofan state, Sudan, seasons 2016 and 2017 was used.

2.2 Methods

2.2.1 Emulsion preparation

Distilled water was added to 12 g of the gum sample (based on dry weight) to become 40 g in total with a concentration of 30 % (w/w) gum solution. The sample was agitated on a tube roller mixer overnight until the sample completely dissolves. Exact calculated grams for each samples (in the range from about 27 to about 28 g) of the prepared gum solution was filtered using 100 µm mesh, then mixed with 0.52 ml of 10 % (W/V) sodium benzoate solution as a preservative, and 0.48 ml of 10 % (W/V) citric acid solution to adjust the pH to 4, distilled water was added until the total weight become 32.0 g. then, 8.0 g ODO oil was added to the gum solution to give a total of 40 g and final concentration of 20%.

The mixed solution was homogenized for 3 minutes using a polytron (PT-2100) homogenizer at 26000 rpm. Impeller (PTDA21 9 mm tip diameter) was used as dispersing tool. To achieve small particle size < 1 micron, the pre-emulsified mixture was homogenized using a high-pressure Nanomizer (NM2-L100, Yoshida a kikai Co. Ltd.). In order to achieve effective disaggregation of the gum, the mixture passed, twice, at 50 MPa.

The final emulsion was divided in two aliquots and kept in closed glass vials. One of the aliquots was kept at 60ºC in the Vacuum Oven (Gallenkamp. OVA031. XX1.5), and the other one at room temperature.

2.2.1.1 Droplet size analysis

Droplet size distribution of the emulsions was analyzed using Mastersizer 3000, a laser diffraction particle size analyzer (Malvern Instruments). Distilled water was used as dispersant and a value of 1.450 was used for the refractive index for oil phase (ODO). Emulsification stability of samples kept at 60ºC was evaluated by particle size change after accelerated stability test for 3 and 7 days.

A particle size emulsion is described by the volume median diameter (VMD).

2.2.2 Rheological measurments

Rheological measurements were carried out using KINEXUS Pro+ (Malvern Instruments) fitted with cone and plate geometry with a cone diameter of 40 mm and an angle of 2^0. Steady shear viscosity curves were measured for gum solutions 25 and 50 % w/v both upon shear rate ramp-up (from 0.01 to 10000 s^{-1}) and subsequent shear rate ramp-down (from 10000 back to 0.01 s^{-1}). Dynamic rheological measurements, to determine the elastic modulus (G′), viscous modulus (G″) and dynamic viscosity, were performed in the frequency range of 0.1–10 Hz. The linear viscoelastic region was assessed, at 1 Hz. The temperature of the samples were controlled within 0.1ºC using a Peltier element. The rheometer control and data processing was done by computer software (Rheology Advantage Data Analysis Program, TA).

3. Results and Discussion

3.1 Emulsification of *A. nilotica* var. *adstringens*

Table 1 and Fig 1 show the span% and mean diameters of cumulative droplet distributions (d0.1, d0.5 and d0.9) measurement of *Acacia nilotica* var. *adstringens* emulsions at different conditions (fresh emulsion and after storage for 3 and 7 days at 60º C respectively).

The fresh emulsion and emulsion stored for 7 days at 60º C show low degree of polydispersity (span %), indicating good uniformity of the droplet size. The span change varies from 2.537 in fresh emulsion to 2.829 for emulsion stored for 7 days at 60º C. However, the specific surface area decreased when the emulsion stored for 7 days at 60º C

Fig 1 shows the particle size distribution of *A. nilotica* var. *adstringens* emulsion (freshly prepared emulsion, emulsion stored for 3 and 7 days at 60º C) is constant (~ 1 micron), indicating a stable emulsion. The particle size of the emulsion was described as volume median diameter (VMD), for *A. nilotica* var. *adstringens* (VMD) was found 0.532µm for fresh emulsion and 0.557µm for emulsion stored for 7 days at 60º C. It is generally known that an increase in droplet mean diameter upon storage is an indicator of droplet coalescence. In relation to emulsion rheology, the occurrence of droplet coalescence will be normally accompanied by a decrease in the emulsion viscosity.

Table 1: Span% and mean diameters of cumulative droplet distributions (µm) of freshly and stored (3 and 7 days at 60º C) emulsions of *Acacia nilotica* var. *adstringens (*whole gum)

	Freshly prepared	**3 days at 60°C**	**7 days at 60°C**
Span %	2.537	416.2	2.829
D [32]	0.0781	0.177	0.0784
D [43]	0.588	146	0.771
d (0.1)	0.0249	0.0487	0.0247
d (0.5)	0.532	1.12	0.557
d (0.9)	1.37	465	1.6

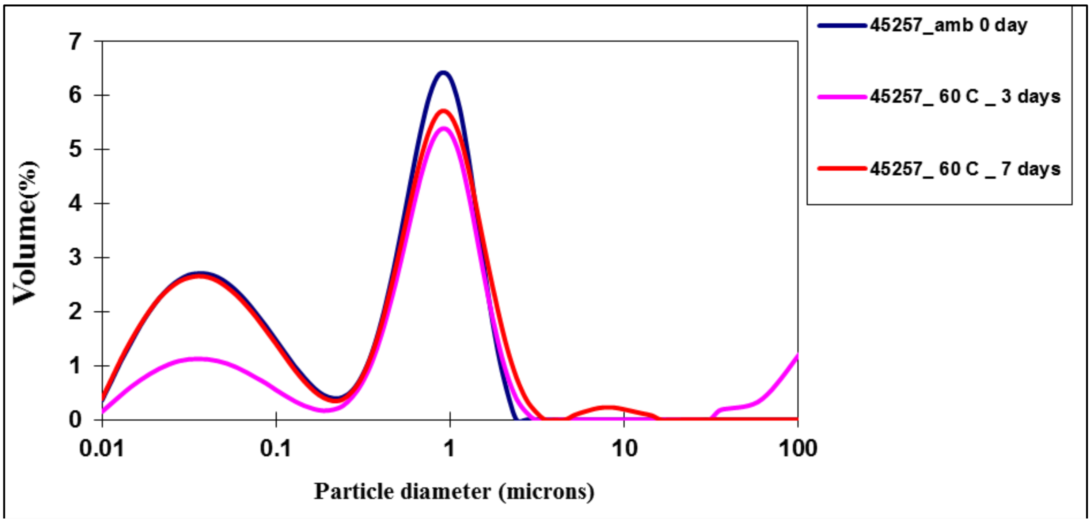

Fig 1: Particle size distributions of *Acacia nilotica* var. *adstringens* emulsion

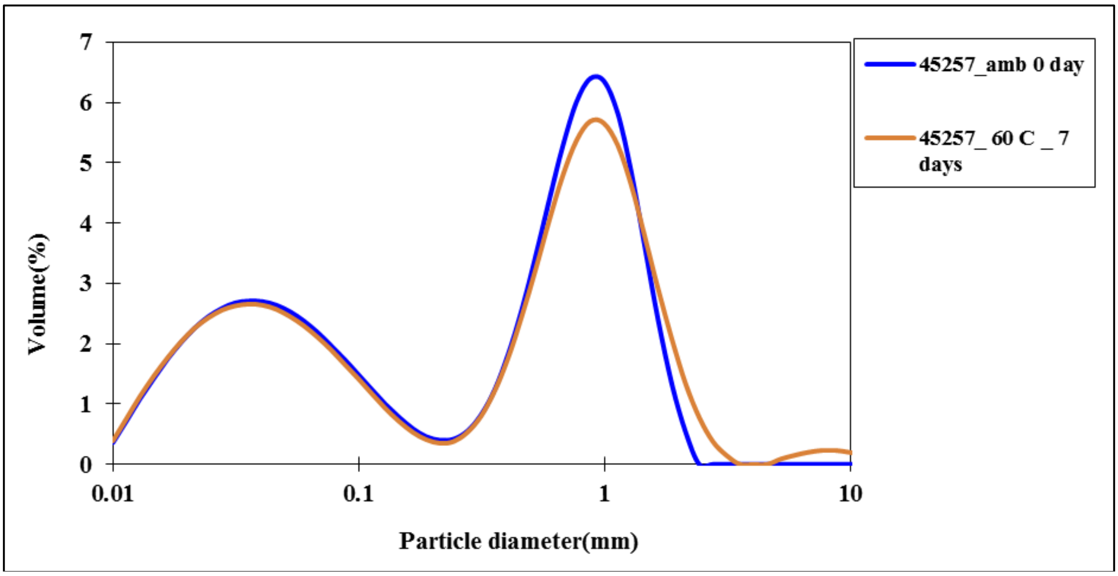

Fig 2: Particle size distributions of *Acacia nilotica* var. *adstringens* emulsion samples (freshly and 7days at 60° C)

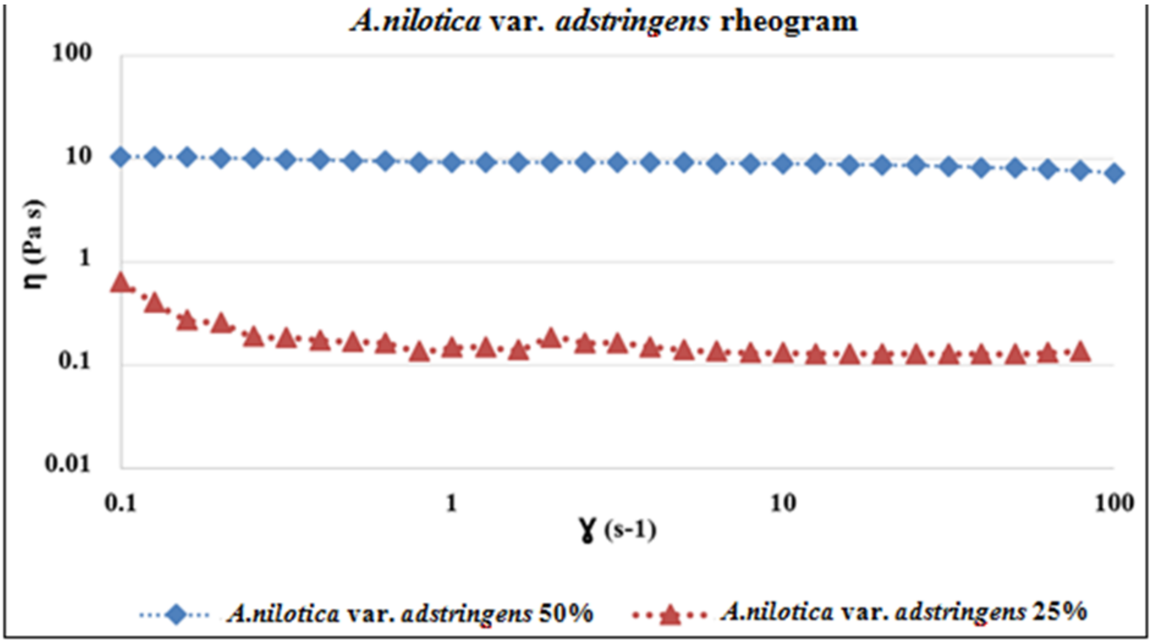

Fig 3: Viscosity-Shear rate profile of *Acacia nilotica* var. *adstringens* gum solution at 25% and 50% concentration

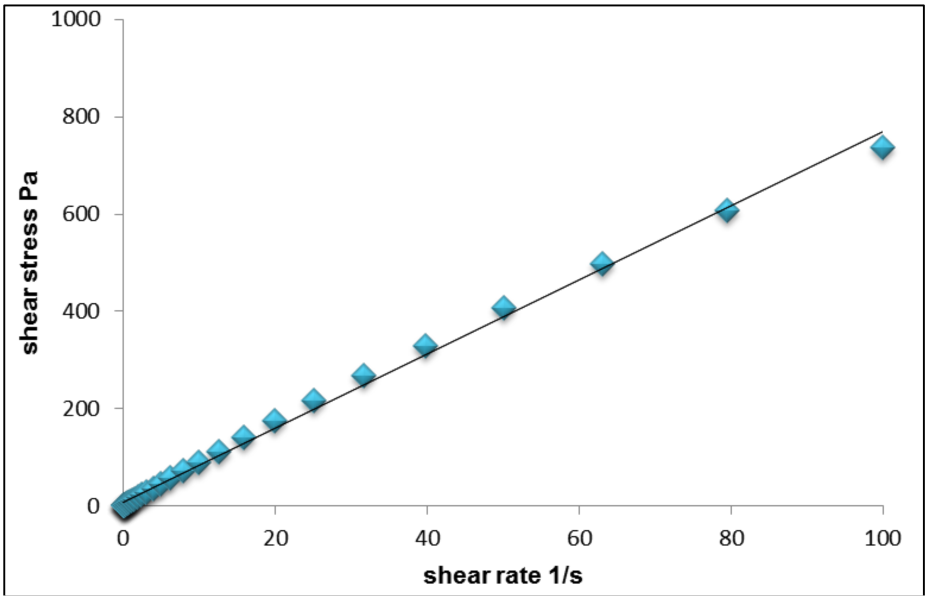

Fig 4: The shear rate vs. shear stress of *A. nilotica* var. *adstringens* gum 50%

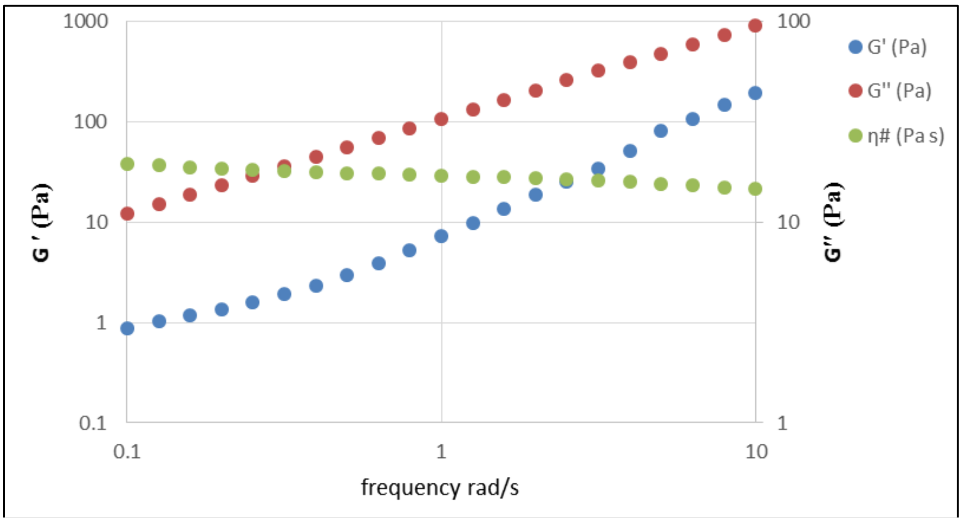

Fig 5: The dynamic rheological behaviour of *Acacia nilotica* var. *adstringens* gum solution at 50% concentration.

3.1.1 Emulsion stability index of *Acacia nilotica* var. *adstringns*

Acacia nilotica var. *adstringens* gum has a high molecular weight of AGP. The stability of emulsion offered by gum of *A. nilotica* var. *adstringens* may be due to the AGP fraction increase. It established that there is a relationship between the proportion of AGP component and emulsion stability (Dickinson *et al*, 1988) [3].

Fig 2 shows particle size distributions of *Acacia nilotica* var. *adstringens* emulsion samples (freshly and 7days at 60° C) which clearly showed that no change was found in most emulsions during the incubation for 7 days at 60ºC.

3.2 Rheology

Figures 3 show the effect of shear rate on viscosity, at 25ºC, for *Acacia nilotica* var. *adstringens* gum solutions of different concentrations. The flow curves at increasing shear rates showed that the apparent viscosity (η_0, Pa.s) decreased slightly as the shear rate (γ˙ s^{-1}) increased. A Newtonian low-shear plateau (the so-called zero-shear viscosity) was observed even at shear rates as low as 0.1s^{-1}. At intermediate shear rates (above roughly 1 s^{-1}) a trend to a high-shear Newtonian plateau was observed. The flow curve show a shear-thinning at lower shear rates, and a viscosity plateau (Newtonian behavior) at higher shear rates (Fig 3). Similar rheological observations have been already reported for gum arabic (Williams *et al* 1990, Mothé *et al*., 1999 and Sanchez *et al*., 2002) [15, 5, 10]. The extent of the shear thinning seems to be reduced at higher concentrations. That may be regarded as arising from modifications in the macromolecular organization of the solution as the shear rate changes. At concentrations of 50% solutions, gum exhibit Newtonian flow. Therefore, the rheological behavior of gum solution approach Newtonian character as the gum concentration increases, Figure 3. Newtonian behaviors were expected as a result of the relatively compact conformation of branched gum (Tanaka *et al*., 2006) [14]. This result is similar to that obtained by (Satti, 2011) [11] for *A. nilotica* var. *nilotica* gum at 50% concentration.

Fig 4 shows that *A. nilotica* var. *adstringens* gum has a typical Newtonian behavior.

3.2.1 Dynamic rheological behavior

Fig 5 shows the dynamic rheological behavior of *A. nilotica* var. *adstringens* gum solution at 50wt% concentration. The loss modulus (G″) was higher than storage modulus (G′) at all frequencies. The energy used to deform the material is dissipated viscously and the sample exhibits liquid-like

behavior. The moduli showed less frequency dependence at lower frequency range and relatively higher
frequency dependence at higher frequency range.

4. Conclusion

- The study shows that *Acacia nilotica* var. *adstringens* gum has a functional ability to act as emulsifier and stabilizes oil in water emulsion similar to *A. senegal*.
- Gum of acacia *adstringens* exhibit Newtonian flow at high concentration.
- The loss modulus of *Acacia adstringens* gum is higher than the storage modulus, which indicates liquid like behavior.

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