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Characterization and Rheological behavior of the gum from *Acacia oerfota*

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Abstract
The physicochemical properties of *Acacia oerfota* gum were investigated. The results show that moisture was in the range of (11.13 - 13.65%), Ash (1.10 - 1.86%), pH (4.55 - 5.28), specific optical rotation (+65 - +80), nitrogen (0.42 - 0.77%), hence protein (2.19 - 3.94%), acid equivalent weight (2941 - 5357), total *uronic* acid (3.62 - 6.60%), calorific value (4.02 - 4.08 Kcal/g), color Gardner (1 - 3), intrinsic viscosity (3.4 - 11.4 cm^3g^{-1}), and the number average molecular weight ($1.68x10^5$ and $1.80x10^5$ g/mol)
Rheological studies indicate a Newtonian behavior of A. *oerfota* gum across a wide range of concentrations and different shear rates, and the molecule can be reformed after the applied stress.
The loss modulus (viscose) G" and storage modulus (elastic) G' carves obtain that A. *oerfota* gum has viscose behavior not changed to elastic or viscoelastic under applying gradual increasing oscillating frequencies.

Keywords: *Acacia oerfota, physicochemical properties, rheology*

1. Introduction
Acacia oerfota is Found in North tropical Africa: Sudan, Chad, Ethiopia, Northern Africa: Egypt, East tropical Africa Kenya, Tanzania, Uganda, Asia temperate Oman, Sudia Arabia, Yemen Western Asia: Iran [1]. *Acacia Oerfota* is the one of the species in series 4 (Gummiferae) of Bentham's classification of the genus [2]. The polysaccharide exuded by *Acacia oerfota* trees as a high, positive specific rotation, has low methoxyl and L-rhamnose contents, and contains D-galactose, L-arabinose, and D-glucuronic acid, which is present in two aldobiouronic acids, 6-*O*-(β-D-glucopyranosyluronic acid)-D-galactose and 4-*O*-(α-D-glucopyranosyluronic acid-D-galactose. The structural evidence suggests that A. *oerfota* gum molecules possess highly branched D-galactan frameworks, to which are attached D-glucuronic acid residues and L-arabinose-containing side-chains, some of which are at least six units long. The gum contains the largest proportion of L-arabinose in any of the *Acacia* gum exudates studied to date [3].
Rheology is defined as the science of deformation and flow [4]. In principle, this definition includes everything that deals with flow, such as fluid dynamics, hydraulics, aeronautics and even solid state mechanics. However, in rheology the intention is to focus on materials that have a deformation behavior in liquid and solid states.
The Rheology behavior of A. *oerfota* gum has never been investigated, accordingly, this work aimed to twofold: Firstly, to understand the relationship between structure and flow properties; This important for the intelligent design and/or formulation of materials for certain applications. Secondly, studying the material behavior using simple deformations, fundamental relations will be derived between deformation and force.

2. Materials and methods
2.1 Materials
Thirty samples were collected from two locations from around Senga city, Sinnar state and Wadel hadad, Aljazeera state, Sudan (15 sample from each area). Several *oerfota* trees were tapped by making incisions about 15cm long and 3 cm wide using an axe. 10 to 20 blazes were made, on branches of the trees. Gum nodules (Fig 1) were collected and dried at room temperature, cleaned by hand, ground using mortar and pestle, and kept in labeled plastic containers for analysis.

Fig 1: *Acacia oerfota* gum sample

2.2 Methods

2.2.1 Physicochemical properties of the gum

Gum samples were analyzed for moisture%, ash%, nitrogen and protein content, specific optical rotation, color gardener, Intrinsic viscosity, Equivalent weight and total Uronic Acid following to AOAC, 1990 method.

2.2.2 The Calorific value

The calorimeter C1 may only be used for the first time in this conduction to determination the calorific value of solid and liquid materials according to national and international standards (eg DIN 51900, BS 1016 T5, ISO1928, ASTM 5468, ASTM 5865 and ASTM 4809). The IKA® C1 calorimeter system, was calibrated by standard IKA® C723 Benzoic acid tabs about 1g (2 Tabs), with cross cal.val. 26461J/g, RSD 0.03%, and LOT SZBD2180V.The temperature was 19 C, the gas pressure (Oxygen) was 30 bar, and the Pump flow 2700 rpm. Then weighted about 0.5g (taking into account the moisture content) of gums samples and placed into plastic bag, big bag or small bag which have cross cal. Val. 46383, and 46463 respectively, the bag was covered by rolling it and placed into a decomposition vessel which is surrounded by a water jacket. The sample was combusted in an oxygen atmosphere, and the calorific value of the sample was calculated from the resulting increase in the temperature.

2.2.3 Rheological measurements

Rheological measurements were carried out using a CVO-R Rheometer Germini TM, Malvern Instrument UK fitted with cone and plate geometry with a cone diameter of 4 cm and an angle of 4. Dynamic rheological measurements to determine the elastic modulus (G'), viscous modulus (G") and dynamic viscosity, they were performed in the frequency range of 0.1–10 Hz. The temperature of the sample was controlled within 0.11C using a Peltier element. The 50-w/w% (based on loss on drying) gum solutions were prepared in water containing 0.005 w/v% NaN3 as a preservative. The samples were tumble mix for 24 h and measurements were carried out at 25 C.

3. Results and discussion

3.1 Physicochemical properties

Table 1. shows the physicochemical properties of *A. oerfota* gum from tow location. The two locations has same moisture content (11,8 - 13.1%) and (11.8 - 13.4%). In comparison to *A. senegal* gum, *A. oerfota* gum has law ash content (1.18 - 1.31%) as compared to (2.87 - 4.89%) for A. *senegal*. The pH of A. *oerfota* gum was measured in 4% concentration and the values is in the range (4.55 - 5.28). showing that A. *oerfota* was slightly acidic due to the presence of free carboxyl groups of D-glucuronic acid residues [1]. The specific optical rotation of A. *oerfota* gum is in the range of (+65 to +80).

Table 1: Physicochemical properties of *Acacia oerfota* gum

Wadal hadad aria					Senga area				
S. code	**Moisture%**	**Ash%**	**pH**	**S.O. Rotation**	**S. code**	**Moisture%**	**Ash%**	**pH**	**S.O. Rotation**
sample1	12.8	1.60	4.55	+75	sample 16	12.37	1.10	4.88	+80
sample 2	12.2	1.86	4.94	+65	sample 17	13.65	1.12	5.09	+70
sample 3	12.5	1.56	4.96	+65	sample 18	11.23	1.16	4.97	+65
sample4	12.7	1.58	4.65	+70	sample 19	11.67	1.24	5.15	+60
sample5	13.1	1.83	5.02	+70	sample 20	13.46	1.22	4.90	+80
sample 6	12.2	1.43	4.88	+80	sample 21	12.90	1.34	5.22	+60
sample 7	12.6	1.62	4.88	+65	sample 22	11.13	1.26	5.09	+80
sample 8	12.9	1.61	4.94	+80	sample 23	12.5	1.28	5.03	+80
sample 9	13.4	1.27	4.97	+75	sample 24	12.67	1.22	5.13	+65
sample 10	11.9	1.83	4.60	+75	sample 25	11.98	1.40	5.26	+65
sample 11	12.6	1.40	4.90	+75	sample 25	12.79	1.30	5.20	+75
sample 12	11.8	1.53	4.90	+70	sample 27	11.21	1.30	5.08	+65
sample 13	12.4	1.16	5.28	+75	sample 28	12.02	1.49	5.26	+80
sample 14	12.6	1.20	4.87	+70	sample 29	12.25	1.29	5.21	+80
sample 15	13.0	1.65	4.90	+75	sample 30	11.98	1.26	5.18	+80
Comp.1	12.2	1.60	4.83	+80	Comp.5	12.35	1.26	4.90	+70
Comp.2	12.6	1.63	4.90	+75	Comp.6	12.47	1.27	5.15	+65
Comp.3	12.9	1.31	4.88	+65	Comp.7	12.33	1.24	5.16	+75
Comp.4	12.5	1.65	4.86	+70	Comp.8	12.16	1.30	5.05	+70
Average	11.9-13.4	1.16-1.86	4.55-5.28	+65 - +80	Average	11.13-13.65	1.10-1.49	4.88-5.26	+65-+80

3.2 Nitrogen and protein content

According to Table 2, the average value of nitrogen and protein content of *Acacia oerfota* gum was found to be 0.53 and 3.28 % respectively. these value is higher than the values of nitrogen and protein content of *A. senegal and seyal*. Anderson (1977) reported that nitrogen content of *A. senegal* gum 0.29% and for *A. seyal* 0.14%.

3.3 Equivalent weight and *Uronic* Acid

Table 2. show the acid equivalent weight and total *uronic* acid% of A. *oerfota* are found to be in the range of (2941 - 5357) and (3.62 -6.60) respectively, this results is determined the high equivalent weight of *A. oerfota* comparing to A. *Senegal* gum which have equivalent weight 1040 [5].

Table 2: Physicochemical properties of A. *oerfota* gums - composite samples

Area name	S. code	Nitrogen	protein	Acid eq. w	Uronic acid%	Intrinsic viscosity
Wadelhadad area	Comp.1	0.49	3.06	3409	5.69	7.86
	Comp.2	0.63	3.94	3571	5.43	11.4
	Comp.3	0.51	3.11	3333	5.82	4.6
	Comp.4	0.49	3.06	2941	6.60	6.8
Senga area	Comp.5	0.35	2.19	5357	3.62	4.6
	Comp.6	0.77	4.81	3846	5.04	7.1
	Comp.7	0.43	2.71	3192	6.08	7.0
	Comp.8	0.42	2.63	3409	5.69	3.4
Range		0.42-0.77	2.19-3.94	2941-5357	3.62-6.60	3.4-11.4

3.4 Intrinsic viscosity

The intrinsic viscosity of *A. oerfota* gum was measured using U-tube Ostwald viscometer. There are no significant different between the two locations. The results are found to be in the range of (3.4 - 11.4 cm^3g^{-1}), these results is law than the results obtained for A. *senegal* 9.7 - 26.5 cm^3g^{-1} [6] and A. seyal 11.9 –17.6 cm^3g^{-1} [7].

Huggins coefficient (k) and (α) was calculated using Mark-Houwink equation, using the relationship between the intrinsic viscosity determined by viscometer and molecular mass determined by GPC-MALLS and they found to be 0.86 and 0.0136 respectively.

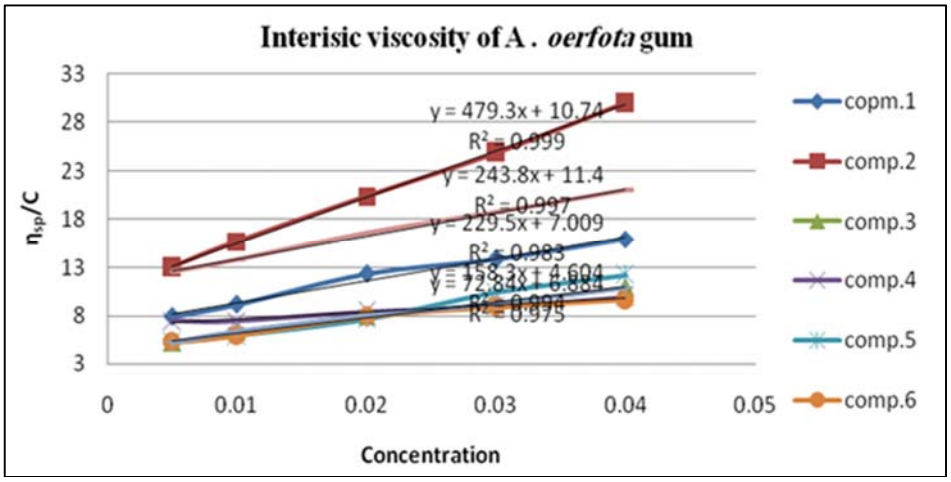

Fig 2: The intrinsic viscosity of A. *Oerfota* gum

3.5 Calorific value

The calorific values of A. *oerfota* gum are closely same as the calorific value of the gums, they were about 4 Kcal/g (Table 3). This calorific value is very low, so the gum are very suitable to be used as food additives or food ingredients.

Table 3: The calorific values of A. *Oerfota* gum

Sample name	Sample location	Sample weight	Bag Cal. value J/g	Cross cal. Value	Net Cal. value J/g	Net. Cal. value. cal/g	Cal Value Kcal/g
A.*oerfota* gum	*Senga*	0.5189	46463	15805	17024	4067	4.067
A.*oerfota* gum	*Aljazera*	0.5066	46463	15596	16829	4020	4.020

3.6 The Rheology

The Rheological behavior of *Acacia oerfota* gum was studded in concentration 25%. According to the fig 4, and fig.5 *Acacia oerfota* has Newtonian behavior as *Acacia senegal* gum [8] (the viscosity is constant with increasing applied shear rate), and the molecules can be reformed after removing applied stress [9]

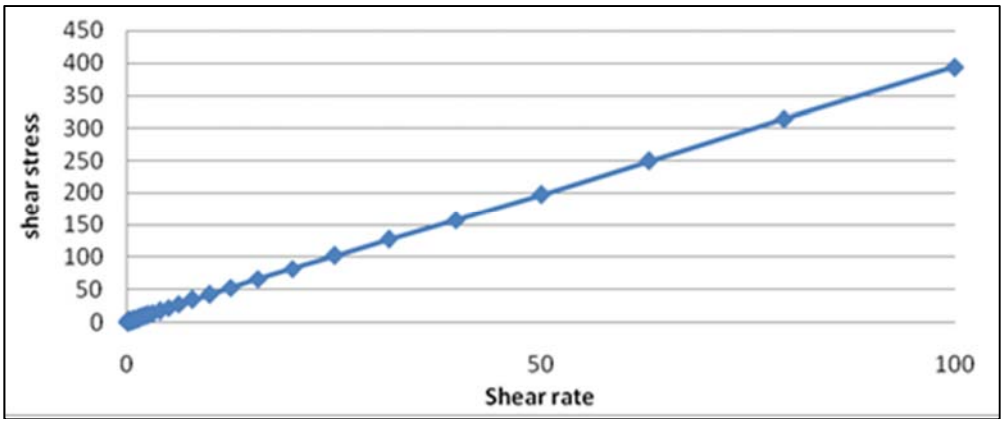

Fig 3: The shear rate V.S shear stress of *Acacia oerfota* gum

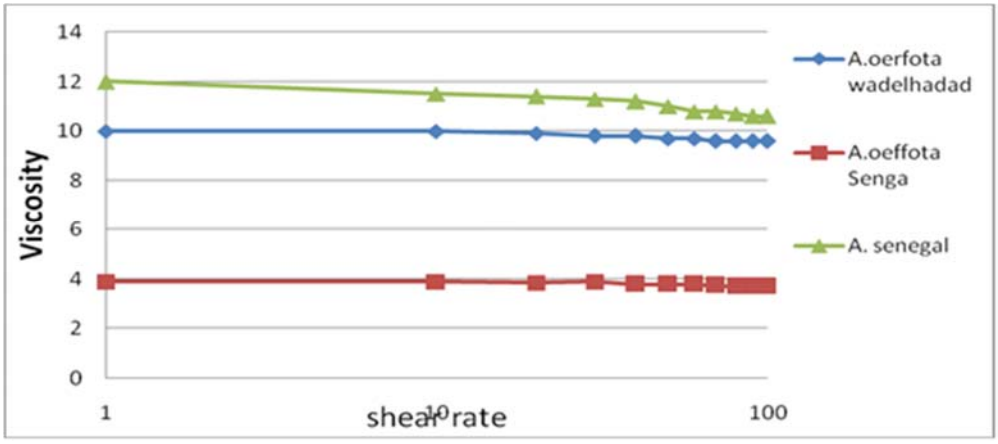

Fig 4: Viscosity profile of *Acacia* gum solution with shear rate - concentration 25%

3.7 The dynamic rheology

Figs 6. shows that the loss modulus (G″) of *A. oerfota* gum was higher than the storage modulus (G′) and they do not cross even at higher frequencies, then A. *oerfota gum* is viscous not, elastic or viscoelastic [8]

The frequency sweep gives information about gel strength where a high slope of the G' curve indicates low strength and a small slope indicates high strength [4]. Both gums show similar gel strength.

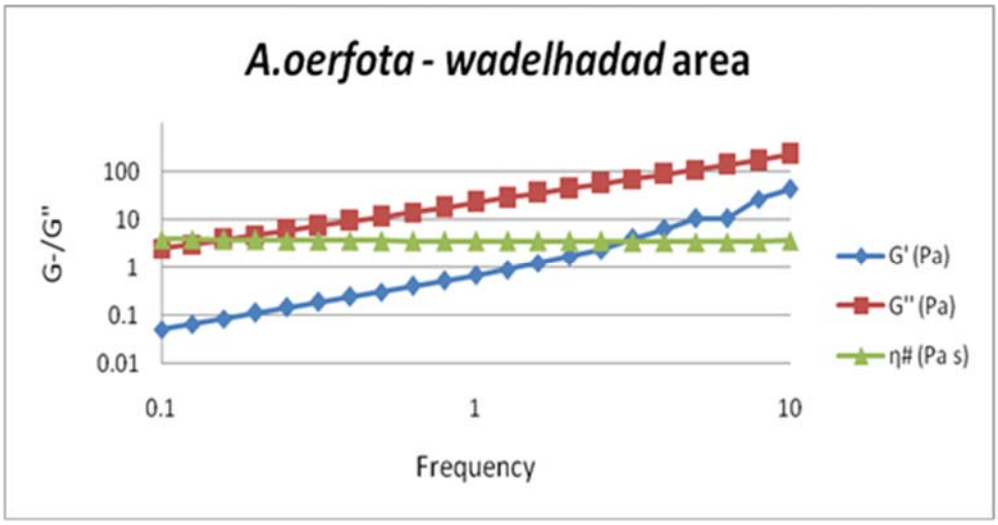

Fig 5: The effects of frequency on G' and G" in A. *oerfota* of two location

4. Conclusion

Acacia oerfota gum shows physicochemical properties reflecting its resemblance to Gummiferae series.

The rheology of *Acacia oerfota* gum show that the gum is simply a Newtonian fluid.

The loss modulus of *Acacia oerfota* gum is higher than the storage modulus.

The rheology characteristics of A. *oerfota* gum is the same as of A. *senegal* gum.

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