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Studies on the rheological properties and functional potentials of achi (*Brachystegea eurycoma*) and ogbono (*Irvingia gabonesis*) seed gums

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Abstract

Water soluble gums were extracted from seeds of achi (*Brachystegea eurycoma*) and Ogbono (*Irvingia gabonesis*). The rheological properties of each gum were studied at temperatures from between 10–70°C at 1.0, 1.5, 2.0, and 2.5% concentrations. The effects of small quantities of the gums on some of the quality characteristics of an ice cream mix were investigated. These characteristics were compared with those of some commercial food gums, carboxymethyl cellulose (CMC), Kappa carrageenan (KCA), and sodium alginate (SA). The viscosities of both gums were time-independent and Ogbono seed gum (OSG) appeared to be more pseudoplastic than Achi seed gum (ASG). The pseudoplastic nature was not affected by increasing temperature. The temperature control was more critical for OSG (E_a. 20.2 MJ mol^{-1}) than ASG (E_a 13.9 MJ mol^{-1}) during processing. The viscosity behaviour of ASG indicates that it may be a highly branched polysaccharide. The overrun, viscosity, shapefactor and meltdown values of the ice cream, when ASG was added as stabilizer, were 95%, 0.035 PaS, 72% and 32%, respectively. Values for OSG were 70%, 0.025 PaS, 65% and 37.7%, respectively. Only values for the ASG cream fell within the ranges of values obtained for the commercial gums.
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1. Introduction

Achi (*Brachystegea eurycoma*) is commonly found along the river banks in Western and Eastern Nigeria. It is a large tree with irregular and twisted spreading branches. The seed has a roundish flat shape with brown colour and hard hull. The fruit ripens from September to January and is released by an explosive mechanism. Ogbono or the African wild mango belongs to the family of Irvingiaceae. It is found mainly in the Southern parts of Nigeria and some parts of West Africa. It is a wild forest tree with dark green foliage and yellowish fragrant flowers. The fruit is spherical in shape with smooth yellow fibrous mesocarp and hard endocarp when ripe. Studies on achi are very scanty but the nutritional composition of ogbono has been reported (Eka, 1980; Ejiofor, Onwubuke & Okafor, 1987). Both seeds, when in powdery form have the ability to swell in water and, thus, are able to influence the viscosity of the liquid. They are known to cause increased viscosity in soups, giving it a more acceptable mouth feel. Outside this culinary use, it may be possible for these gums, when used as additives in other foods, to impact desirable textural and functional properties to the finished food products, particularly the ‘‘convenience foods’’ which contain one or more gums.

This present work was aimed at studying the rheological characteristics of the colloidal substances extractable from these seeds and the effects of small quantities of these gums on some physical properties of an ice cream mix. This effect will be compared with that of some well known commercial gums.

2. Materials and methods

2.1. Preparation of raw materials

Achi seeds (AS) and ogbono seeds (OS) were obtained from a local market. Clean and wholesome seeds were selected. AS were decoated by roasting in an open pan, and cooled immediately by the addition of water. The cracked hull was washed off with several

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changes of water. The dehulled AS were softened by soaking in water for 24h at 27°C before milling. The seeds were milled in a manually driven attrition mill. The powder so obtained was packaged in an air-tight bottle and stored at 4°C. OS were dehulled by scraping off the hull using a sharp stainless knife. The dehulled seeds were milled and stored as above.

2.2. Extraction of the colloidal substances

The method for the extraction of colloidal substances was that of Ratbort, Neeman, Nussinovitch, Kelpman and Colian (1988). Each powder preparation (95 g) was hydrated with 400 ml of water and kept at 60°C. The resulting slurry was treated with calcium hydroxide (19 g) for 3 h at 100°C. The calcium hydroxide was removed by centrifuging, and the pH adjusted to 7. The hydrocolloid was precipitated with 400 ml of propan-2-ol (Analar®). Precipitated colloid was dried at 60°C (3 h), milled into fine powder and stored at 27°C in an air-tight bottle.

2.3. Viscosity measurement

Dispersions in concentrations of 1%, 1.5%, 2% and 2,5% (w/v) of AS gum (ASG) and OS gum (OSG) were made. Apparent Viscosity of each dispersion was measured at 10, 30, 40, 50 and 70°C using the LV model viscometer (Brookfield Engineering Laboratory Inc., Stoughton Massachusetts) at 6, 12, 30, and 60 rotational speeds.

2.4. Preparation and measurement of quality characteristics of ice-cream mix

Methods of formulation of an ice-cream mix and measurement of the quality characteristics were basically those of Cottrell, Rass and Phillips (1979). ASG, OSG and the commercial gums (CMC, KCA and SA) were separately used as stabilizers at a level of 0.2% (w/v). The control sample did not contain any stabilizer. The viscosity (μ), overrun (OR), meltdown (MD) and shape factor (SF) were measured.

3. Results and discussion

3.1. Viscosity behaviour

Figs. 1(A–E) and 2(A–E) show the log-log plot of apparent viscosity, μ_{app} of the different concentrations of ASG and OSG against shear rate (γ) at temperatures

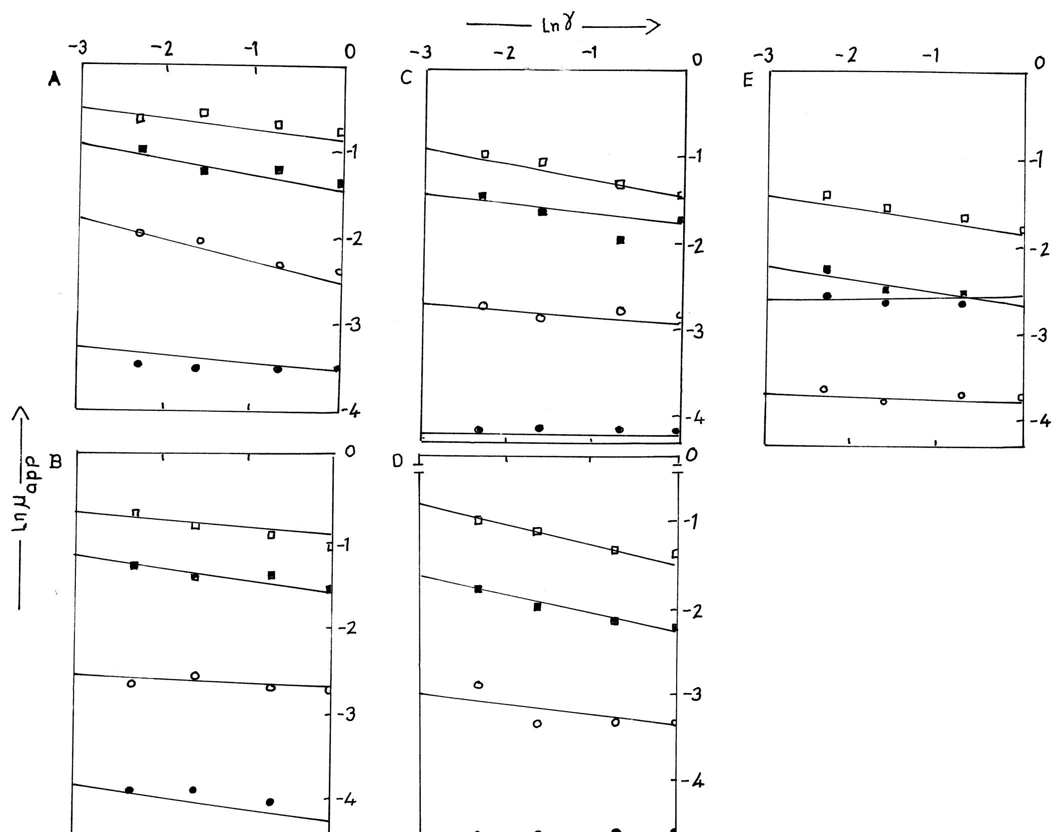

Fig. 1. Log of apparent viscosity versus log of shear rate at different concentrations (1%, □—□; 1.5%, ■—■; 2.0%, ○—○; 2.5%, ●—●) and temperature (10°C, A, 30°C, B; 40°C, C; 50°C, D; 70°C, E) of ASG.

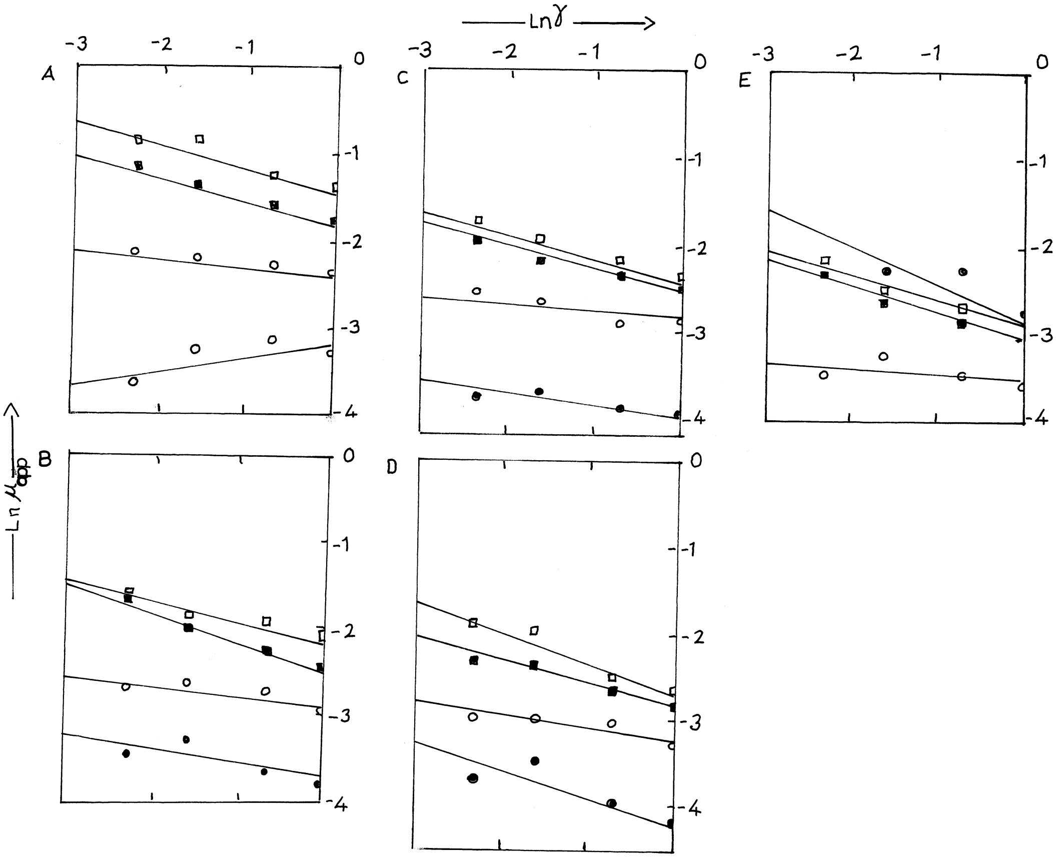

Fig. 2. Log of apparent viscosity versus log of shear rate at different concentrations (1%, □—□; 1.5%, ■—■; 2.0%, ○—○; 2.5%, ●—●) and temperature (10°, A, 30°C, B; 40°C; 50°C, D. 70°C, E) of OSG.

ranging from 10 to 70°C (283 to 343 k). For both gums the apparent viscosities depended on the concentration, temperature and shear rate. These observations were described by means of the power law equation.

$$\mu_{\mathrm{app}} = k\gamma^{(n-1)}$$

Where '*k*' is the consistency or viscosity index and '*n*' the power law index. Finney (1973) observed that, for Newtonian fluids, $n=1$; for pseudoplastic fluids, $0<n<1$ and in dilatant fluids $1<n<\infty$. The results of this work show that the viscosities of both gums were time-independent and the power law model was successful in correlating the data at the different concentrations and temperatures. There was no linear correlation between the log of μ_{app} and γ at 1% concentration for ASG and the '*n*' values obtained at the experimental temperatures suggest a Newtonian behaviour (Fig. 1 (A–E)). The '*n*' average was 0.966 ± 0.05 (Table 1.) The pseudoplasticity of both gums decreased with increase in concentration. It was also observed that the apparent viscosities decreased with increase in temperature. This effect, according to Garcia-Ochoa and Casas (1992), is reversible and it is due to the interactions of the molecules in solution which become weaker at higher temperature. The '*n*' value of 1.16 at 1% concentration and 10°C suggest that a dilatant behaviour may have been due to an inherent equipment error in measuring the low viscous fluid. Generally, OSG appeared to be more pseudoplastic than ASG.

It is important to note that, although, temperature altered the viscous nature of the gums, it did not affect the pseudoplasticity. The changes in '*n*' values with temperature were found to be of a negligible magnitude when compared with that of the consistency index, This was in agreement with Olorunda and Tung (1977). Sapode and Kassum (1992). The temperature dependence of the consistency, index, k, was assessed using the Arrhenius equation

$$K = Lnk_o - \frac{E_a}{R}\frac{1}{T}$$

where K_o = consistency index at $T=\infty$

E_a = activation energy

R = gas constant

T = absolute temperature

Table 1
Summary of the regression analysis and the power law equation of ASG and OSG

		ASG			OSG		
Concentration (%)	Temperature (°C)	Consistency index (*k*)	Power law index (*n*)	Correlation coefficient (*r*)	Consistency index (k)	Power law index (n)	Correlation coefficient (r)
1	10	0.029	0.95	−0.63	(0.04	1.16	0.75
	30	0.015	0.88	−0.93	0.024	0.86	−0.67
	40	0.015	1.00	–	0.018	0.84	−0.96
	50	(0.01	1.00	–	0.014	0.70	−0.84
	70	0.07	1.00	–	0.058	0.59	−0.83
			0.966 ± 0.08			0.83 ± 0.21	
1.5	10	0.085	0.79	−0.99	0.09	0.88	−0.88
	30	0.065	0.98	−0.95	0.054	0.90	−0.92
	40	0.058	0.94	−0.98	0.06	0.95	−0.32
	50	0.035	0.85	−0.74	0.038	0.86	−0.95
	70	0.02	0.99	−0.08	0.028	0.93	−0.50
			0.91 ± 0.08			0.90 ± 0.04	
2.0	10	0.256	0.86	−0.95	0.167	0.75	−0.99
	30	0.2	0.87	−0.99	0.08	0.68	−0.99
	40	0.15	−0.84	−0.7	0.08	0.77	−0.99
	50	0.11	0.81	−0.98	0.06	0.77	−0.99
	70	0.07	0.89	−0.76	0.04	0.675	−0.998
			0.854 ± 0.03			0.73 ± 0.05	
2.5	10	0.45	0.915	−0.90	0.25	0.76	−0.97
	30	0.40	0.95	−0.756	0.108	0.75	−0.98
	40	0.25	0.85	−0.995	0.09	0.73	−0.969
	50	0.252	0.85	−0.99	0.067	0.64	−0.996
	70	0.162	0.86	−0.99	0.056	0.70	−0.98
			0.885 ± 0.04			0.72 ± 0.05	

The activation energies were calculated for both gums at 2.5% concentration. Values obtained were 13.9 MJ/mol (correlation coefficient = 0.95) and 20.2 MJ mol (correlation coefficient = 0.97), respectively (Fig. 3), This observation suggests that temperature control will be more critical for OSG during processing. Fig. 4 shows the effects of concentration and temperature on the apparent viscosity of the OSG and ASG in solution measured at 60 rpm shear rate. At concentrations of 1.5 and below, both gums exhibited low viscosity. However, at concentrations above 1.5% there was a remarkable increase in the viscosity reading for ASG. At 2.5%, viscosity of ASG was about 6-fold that at 1.5% while OSG viscosity at the same concentration was about two-fold (Fig. 4) Lin and Huang (1993), working with taro (*Colocasia esculenta*) gum, concluded that an interdependent relationship between viscosity and concentration is an indication of a highly branched structure in the gum, and that there are multiple association points existing among the gum molecules.

It is therefore possible for the ASG to possess a more branched structure that resulted in multiple interaction and the consequent increase in viscosity with increasing temperature,

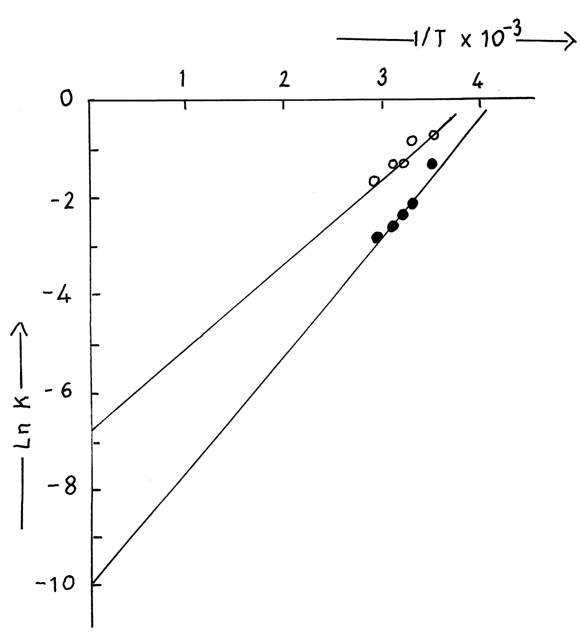

Fig. 3. Plot of the reciprocal of absolute temperatures (I/T) versus Lnk. ○—○, OSG and $k_o = -10.13$, $r = 0.97$; ●—●, ASG and k_o –6.65, $r = 0.95$.

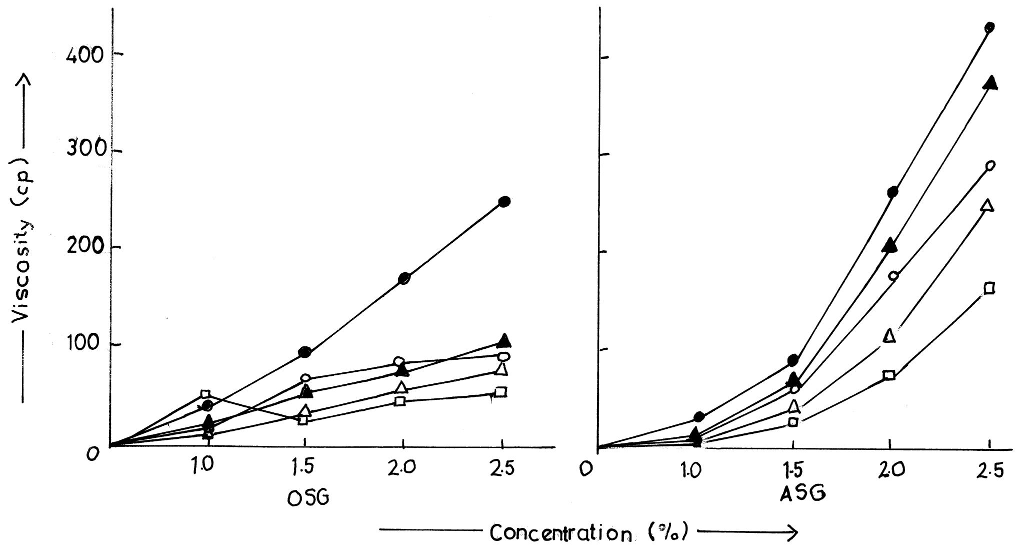

Fig. 4. Effect of concentration and temperature on the apparent viscosity of the gums measured at 60 rpm (10°C, ●—●; 30°C, ▲—▲ 40°C, ○—○; 50°C, △—△; 70°C □—□).

3.2. Quality characteristics of ice cream

The primary reason for using a stabilizer in an ice cream is to aid in the maintenance of a smooth texture by preventing large ice crystal formation (Goff, Dickinson & Walstra, 1993; Farkas & Glicksman, 1967). The most commonly used stabilizers in ice cream are sodium carboxymethyl cellulose, locust bean gum, sodium alginate, propylene glycol alginate, carrageenan and guar gum. The stabilizer in the ice cream may be blends of two or more and each blend differs in its effect on mix viscosity, ease of dispersion in mix body, texture and melting characteristics.

The increase in volume of mix as it is frozen is technically referred to as overrun (OR) which is a measure of the amount of air in the product. Ice cream of low OR tends to be dense and soggy. If the OR is excessively high, the ice cream becomes fluffy and lacks body. The OR values for the mixtures in this study vary from 70–125%. The effect of the different gums on selected properties of the cream is given in Table 2. SA produced the highest maximum OR (125%), viscosity (0.4 PaS) and shape factor (80%) and the lowest meltdown value (20.5%). Quality characteristics of the KCA mix compared well with that of SA, with the exception of the meltdown value (Table 2). Values of these characteristics for the ASG mix were comparable to that of CMC mix in terms of OR and viscosity, while the values for the shape factor (72%) and meltdown (32%) were very similar to that of KCA.

Table 2
Quality characteristics of the ice cream mix using different water soluble gums

Water-soluble gum	Maximum overrun (%)	Viscocity ($\times10^{-3}$ PaS)	Shape factor (%)	Meltdown (%)
CMC	90	28	75	36.9
SA	125	40	80	20.5
KCA	110	35	71	30
ASG	95	35	72	32
OSG	70	25	65	37.7
Control	78	15	63	65

Quality characteristics of the OSG cream appeared to be close to that of the control sample even though OSG imparted some viscosity to the mix, the ability to trap and hold air (OR) and the tendency to resist melting, which are requirements of a satisfactory ice cream, were found to be poor. Thus, the findings suggest that, OSG may not be suitable as a stabilizer in an ice cream.

The rheological behaviour of both ASG and OSG shows both gums are pseudoplastic and the reduced viscosity with increased temperature did not alter this characteristic. OSG appears to be more sensitive to temperature control. The effect of concentration and temperature on the apparent viscosity shows that ASG may probably be a polymer with more branched structure than OSG. When the gums were used differently in the formulation of an ice cream, ASG gave a relatively, better quality cream. ASG may be a potential component for a stabilizer blend and the functionality of the gum in the food industry may be of importance. Further work may be needed to explore these possibilities.

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