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Cissus Stem Gum as potential dispersant in pharmaceutical liquid systems: rheological characterization

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ABSTRACT

A Co-axial viscometer, the Haake-Rotovisco, was used studying the rheological behaviour of aqueous dispersion of cissus stem gum. At concentrations of 4% w/v and above, the mucilage is both pseudoplastic and thixotropic. Two equations derived from a power law expression for apparent viscosity(h): $h = e^{kc+b}$ were solved simultaneously (c = 4 and 8 % w/v) in the determination of material constants *k* and *b* for cissus gum. The apparent viscosity of the polymeric liquid system was affected by concentration of the gum, pH, temperature and aging.

KEY WORDS: Cissus; Dispersant; Rheology; Viscosity; Pseudoplastic.

INTRODUCTION

The plant *cissus refescence family Amphelidaceae* is a climbing stem widely distributed in many parts of Nigeria especially within the guinea savannah region. In Kogi and Benue States of Nigeria, the Igala and Idoma ethnic groups refer to this plant as "Okoho" and use the mucilage from the stem as thickener in broth. In some Northern parts of Anambra State the plant is known as "Ukoho" and mucilage from the root is similarly used in broth. Rheology is the study of flow of matter [(1)] describing the deformation of solids and flow of liquids. There are different types of flow, which can be characterized by rheological concepts and from these, the stability and consistency of creams, suspensions, ointments and all other series of dermatologicals could be studied. The rheological properties of all pharmaceutical preparations are of importance in maintaining the uniformity and standard of preparations [(2)]. A good medium should have a yield value, yet it should be capable of being poured from the bottle [(3)].

Evaluation of substances which would alter the flow properties of the dispersion medium has been a subject of much investigations [(2, 3, 4)]. Correlation of suspending properties to rheological parameters for some hydrocolloids have been made [(3, 5, 6)]. It has been shown that pH, homogenization and heat influence the apparent viscosity of many pseudoplastic polymers including tragacanth mucilage [(7)].

One point measuring viscosimeter is not ideal for rheological characterization. The Brookfield synchroelectric viscosimeter has been used for rheological characterization of pharmaceutical systems [(8)].

Measurement of the viscosity of guar gum with the rotation shear-type viscosimeter showed that it exhibits typical non-Newtorican flow [(7)] where viscosity is at variance with shear rate. Rheology of Albizia mucilage has been studied using the Ferranti-shirly portable viscosimeter. In this investigation, the characteristic flow behaviours exhibited by cissus stem gum mucilage was studied using a Haake Rotovisco viscosimeter that has previously been used in this laboratory for rheological study [(9)].

EXPERIMENTAL

Materials

Acetone (Pharmachem Ltd, England); Sodium Hydroxide (May and Baker); Calcium Chloride (Merck), Tragacanth (Merck), Aluminum Sulfate (Merck); Methylparaben (Sigma), Ethylparaben (Sigma), Benzoic Acid (Sigma). Stand fluid of known viscosity (Brookfield Eng. Labs. Inc.). These chemicals purchased from the manufacturers were tested before use.

Extraction

The fresh *cissus* stem used here was obtained from Otukpo, Benue State. After peeling the back and removing the pulp, some pieces of the fibre, 200g in weight was placed in a stainless steel vessel. Sufficient amount of deionised water was added and the container properly covered. The mixture was macerated for 24 h and the menstrum was strained to obtain a clear mucilage, which was treated with acetone. The precipitated gum was dried at 50°C in a hot-air oven (B & T Searl Coy), milled in an end runner mill (Pascal Engineering Co. Ltd, England) and the fraction which passed through a 150 mm stainless steel sieve was collected and stored.

Apparatus

The co-axial viscosimeter is made up of stand, a tampering vessel, and a control unit having a speed range in 10 fixed steps and a specific speed factor, μ. Accessories include a dual measuring head (type DMK 500/50) with torque ranging from zero to 50 g/m and 0 to 500 g/cm; 3 sensor systems of different cylinder and rotor dimensions. The cylinders with narrow gaps are suitable for materials of low viscosity whereas highly viscous systems require the use of those with wide gaps.

The instrument constant(k) for the three sensor systems were determined through calibration (at 25° ± 0.1°C) by using a standard fluid of known viscosity supplied by Brookfield Engineering laboratories Inc. Massachusetts U.S.A in accordance with the expression:

$$k = \frac{\eta}{\mu.\ s.} \qquad \text{(i)}$$

where h is viscosity of the fluid in cps, μ is speed factor and s is average of three instrument determinations. Values are presented in Table I. The sensor NV with a calculated constant of 0.059 was selected and used in this study. The sensor to be used was fixed onto the instrument and the scale reading was set to zero in air at 50 and 500 measuring heads by operating the instrument at viscosimeter speed of 64.8 rpm or 97.2 rpm respectively.

Preparation of mucilage

Appropriate quantity of the gum was weighed and placed in an Erlenmeyer flask. A half-portion of the required volume of deionized water was added and the flask was covered.

The sample was allowed to hydrate properly for 24 h at 29 ± 1°C and thereafter the volume was made up with deionized water, and stirred mechanically so as to obtain a homogeneous mixture.

Type of flow

Batches of aqueous dispersion of cissus gum were prepared at 1, 2, 3, 4 and 8 % w/v respectively. A volume of 7.5 ml was withdrawn from a sample at a time and placed in the viscosimeter sensor. The rotation was varied between 3.6 rpm and 97.2 rpm and the scale readings for both up and down sweeps were recorded and used for calculating the shear stress.

Effect of concentration

The viscosity of the systems prepared at different concentrations of 1 to 8% w/v were determined at a speed of 7.2 rpm.

Effect of temperature

The viscosity of 2 % w/v mucilage was determined at 25, 30, 35 and 40°C respectively at instrument speed of 7.2 rpm.

Effect of electrolytes

Sodium chloride, calcium chloride dihydrate and aluminum sulphate octahydrate were used. The 2 % w/v dispersions of the polymer liquid systems were prepared so as to contain 0.1 M of a given salt. A control batch of 2 % w/v dispersion contained no electrolyte. The instrument reading of each sample was taken at a speed of 32.4 rpm and the apparent viscosity calculated.

Table I. Calculated constants, *k* for the three sensor systems of the Haake-Rotovisco viscosimeter

Sensor System	Dimensions (mm) Cup Diameter	Rotor Diametr	Rotor height (mm)	*k*
NV	42	40.8	7.2	0.059
MV	42	40.8	61.4	0.261
SV	23.1	40.8	61.4	2.572

Effect of pH

Batches of 2 % w/v dispersions of cissus gum were prepared such that the samples' adjusted pH was in the range of 2 to 11 using NaOH or HCl. The batch prepared without the addition of either alkali or acid served as the control. The instrument reading of each sample was recorded at viscosimeter speed of 32.4 rpm and the viscosity calculated.

Effect of additives

Batches of 2% w/v dispersion of cissus gum were prepared so as to contain either 0.1% benzoic acid, 5% alcohol, 0.05% ethylparaben, 0.15% methylparaben or 0.2% w/v sodium chloride. The pH and viscosity of each sample was determined at zero time and thereafter, those containing ethylparaben, methylparaben or benzoic acid were stored for one week and the measurement was repeated.

Effect of aging

A 3% w/v dispersion of the polymer was prepared so as to contain 0.15% w/v methylparaben as preservative. The viscosity of the system at 29 ± 0.1°C was determined 24 h after preparation and thereafter monitored on weekly basis for a total of six weeks at viscosimeter speed of 7.2 rpm.

RESULTS AND DISCUSSION

The rheograms presented in figure 1 shows that at concentrations of 1 - 3 % of cissus gum, the viscosity of the dispersions remains the same at any given share rate for both the up and downward sweeps. The trend is different at 4 % w/v and above as the share stress for the down sweep was found to be lower than that of the upward sweep at any given share rate. The indication is that this new polysaccharide gum exhibit pseudoplastic and thixotropic flow behaviour at concentrations of 4 % w/v and above. This observation is similar to previous results obtained with some other polysaccharide gums [10, 11]. Acacia exhibited pseudoplastic flow characteristics at concentrations above 20% w/v. Pseudoplastic systems have been shown to obey the power law equation [12, 13]:

$$F^N = \eta D \qquad (i)$$

where D is rate of shear, F = shear stress, h is apparent viscosity and N is an index which describes the behaviour of the liquid system. Expressing this equation in logarithmic form (ii) is obtained:

$$\text{LogD} = \text{NlogF} - \log\eta \qquad (ii)$$

A plot of LogD versus F (figure 2) enables determination of the N values. An index (N)=1, >1 or <1 indicates Newtonian, pseudoplastic or dilatant flow behaviour respectively. Table II shows the values of N determined from figure 2 to be greater than unity for the dispersions at 4 or 8 % w/v: an indication of pseudoplasticity which is in agreement with the characteristic rheograms reflected in figure 1.

Fig. 1. Rheograms of cissus gum dispersions (A = ascending phase and D = descending phase)

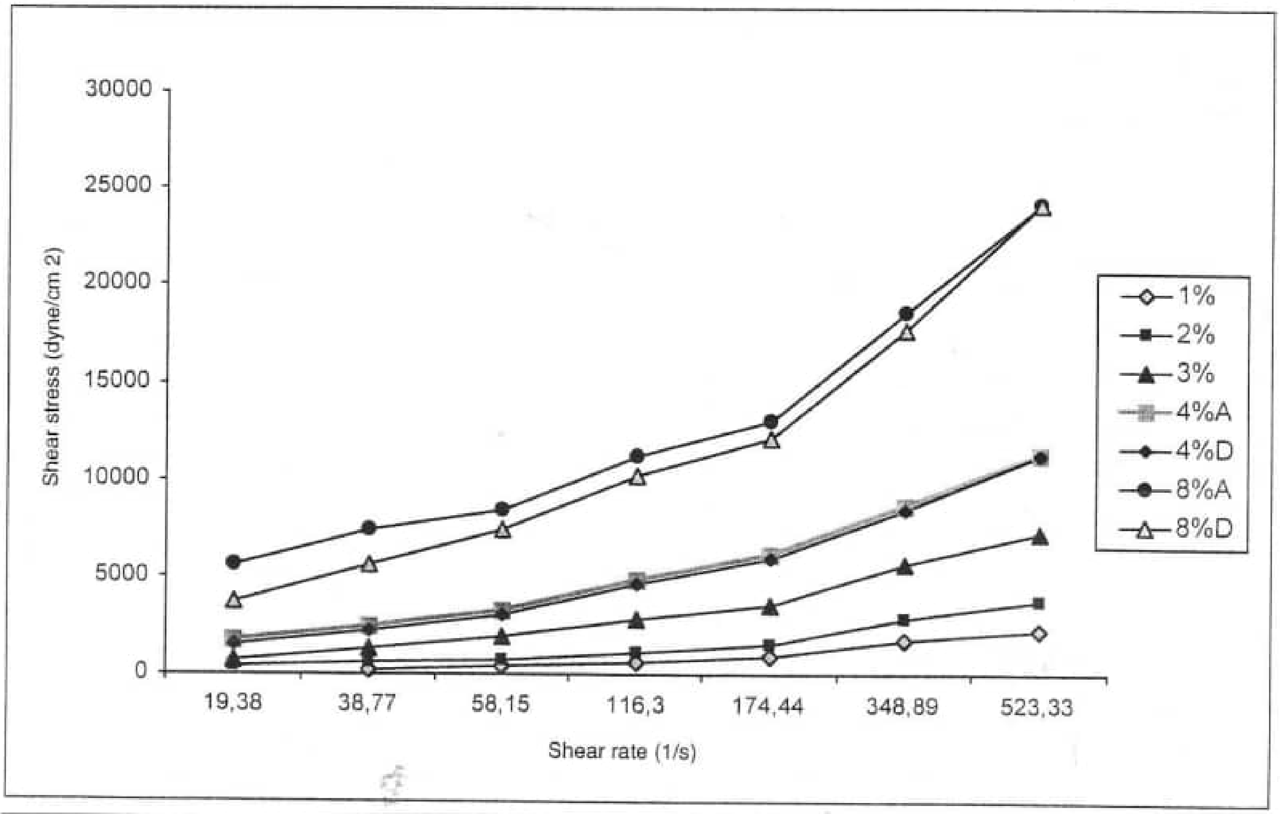


Table II. Effect of concentration of cissus gum on flow parameters

Concentration % w/v	Log h	Fllow Index
4	4.27	1.7
8	7.78	2.4

Fig. 2a: Log-Log plot for cissus gum mucilage at 4% w/v
Fig. 2b: Log-Log plot for cissus gum mucilage at 8% w/v

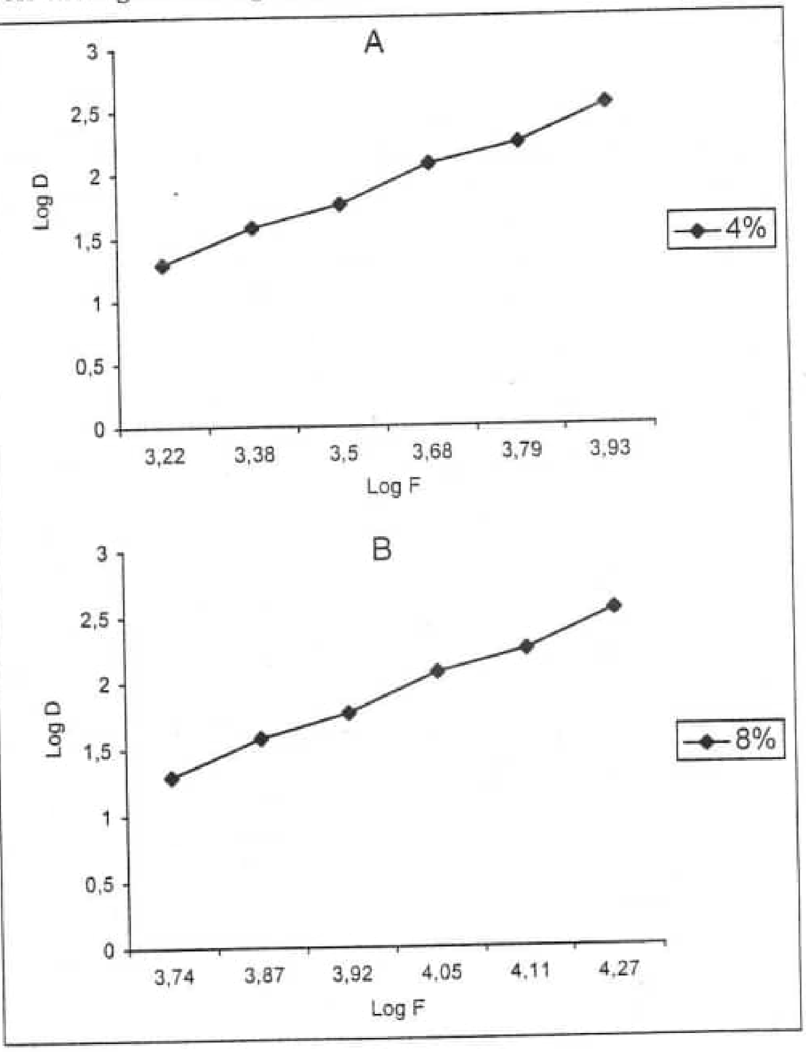


Figure 3 shows that the apparent viscosity of cissus mucilage increases with concentration.
As the concentration of the gum increases, more molecules of water get involved in the polymer - water hydratation network which leads to strengthened crystal lattice bond with consequent increase in resistance to flow. Similar trend has been exhibited by albizia gum as reported by Mital and Adoty (2).
Material constants have been found useful in determining the concentration (c) of some pseudoplastic polymers necessary to give a desired apparent viscosity (η) on the basis of equation (14):

$$\eta = e^{kc+b} \qquad \text{(iii)}$$

where k and b are material constants. Equation (iii) can be expressed as:

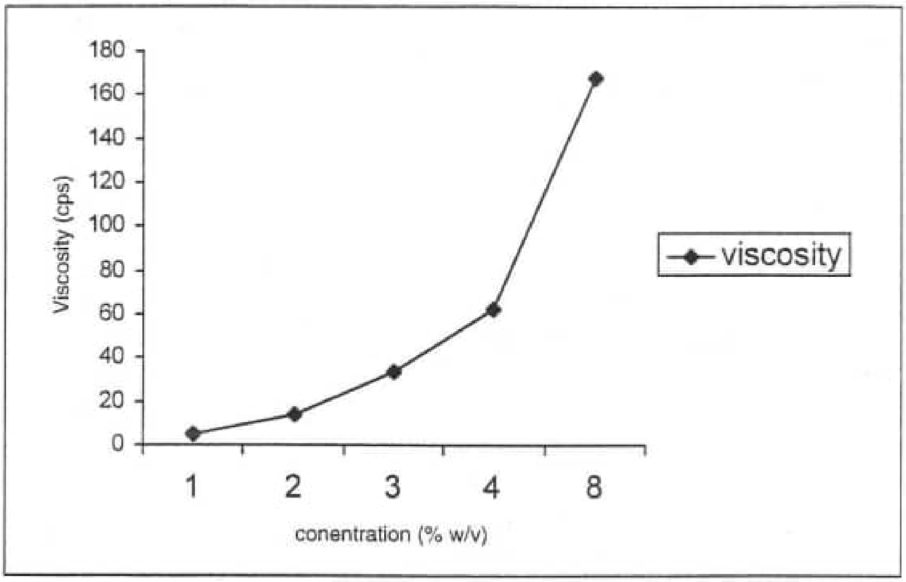
$$\text{Log}\eta = \frac{1}{2.303}\ (kc + b) \qquad \text{(iv)}$$

and substituting the c and Log$h$ values in table 1 enables the formation of two equations:

$$9.83 = 4k + b \qquad \text{(v)}$$
$$16.77 = 8k + b \qquad \text{(vi)}$$

On solving equations (v) and (vii) simultaneously, the material constants, k and c were determined to be 1.733 and

Fig. 3. Effect of concentration on the viscosity of cissus gum dispersions



2.902 respectively and these parameters could be used to calculate the concentration of cissus gum that would give a desired apparent viscosity.

The effect of temperature on the viscosity of 2% w/v dispersion of cissus gum is shown in figure 4. It was found that no appreciable difference in viscosity occurred between 0 to 30°C, above which a notable decrease in resistance to flow resulted. A plausible explanation is that at temperatures above 30°C, there is progressive breakage of the hydrated bonds leading to a reduction in the resistance to flow and consequently, lower viscosity values. Mital and Adotey [2] have similarly reported a decrease in viscosity of polysaccharide mucilage with temperature.

The effect of 0.1M concentration of different electrolytes on the viscosity of cissus mucilage is shown in Table II. The control sample had the highest viscosity of 14.3 cps. Aluminum sulphate octahydrate had the greatest influence in lowering the viscosity to as low as 2.6 cps. Sodium chloride with no water of hydratation exerted the least effect on the viscosity. The influence of the electrolytes thus appear to increase as the hydratation number increases.

The observation here might be due to salting-out effect, in which the electrolyte acts by withdrawing water molecules from the colloidal particles (14). The effectiveness of electrolyte acting in such a system is dependent upon the affinity of its ions for water molecules (hydratation propensity) and valence characteristics. The result shows that the higher the valency of the cation, the greater the effect on

Fig. 4. Effect of temperature on the viscosity of 2% w/v dispersion of cissus gum

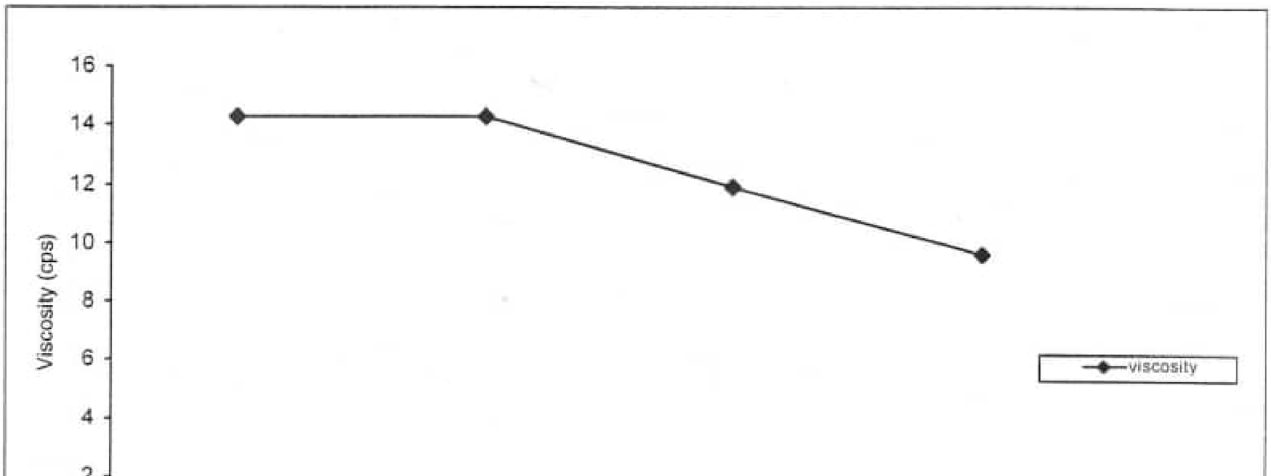


Table II. Effect of electrolyte on the viscosity of 2 % w/v cissus gum mucilage

Electrolyte	viscosity (Cps)
Nil	14.3
Nacl	7.4
$CaCl_2 \cdot 2H_2O$	6.4
$Al_2(SO4)_3 8H_2O$	2.6

the viscosity of the mucilage. This trend is in agreement with the Hofmeister or lyotropic series rule [14, 15]. The effect of pH on the viscosity of cissus mucilage is presented in figure 5. A maximum viscosity of 17.7 cps was recorded at pH of 9.6. At pH of 3 and below, the viscosity is adversely affected and dropped to a level as low as 2.2 - 5.8 cps. The resistance to flow was found to be minimally affected at pH 7 - 9 whereas at alkaline pH of 10 - 11, viscosity again dropped to 7.4 - 9 cps. The indication is that this new polysaccharide gum at pH range of 7 - 10 could manifest optimum thickening activity. The lowering of viscosity at highly acidic or alkaline conditions observed here could be attributed to high degree of precipitation of the gum from the homogeneous disperse system at the extreme pH levels. Agents, which alter the pH of aqueous dispersions of gums, have been reported to do so by precipitation and hydrolysis [15, 16]. The effect of additives on the rheological properties of polysaccharide gums has been investigated by Kassem and Mattha [16]. Similarly, the effect of additives on the pH, viscosity and physical characteristics of 2 % w/v aqueous cissus system was evaluated in this study and the result is presented in Table III. No precipitation or pH changes occurred in the batch containing 5% w/v ethanol. Dispersions containing the parabens and sodium chloride did not show any significant change in pH, viscosity or physical characteristics. Benzoic acid on the other hand reduced the pH of the mucilage from 6.3 to 3.3 with obvious precipitation and a reduction in the viscosity from 14.3 to 7.2 cps. At the end of 1 week storage period, the viscosity of cissus dispersion containing the parabens increased from 14.3 to 19.1 cps whereas that of the batch containing benzoic acid dropped from 7.2 to 4.8 cps. The parabens, ethanol and sodium chloride could therefore be used in dispersions containing cissus gum at the stated concentrations. This cannot be applied to benzoic acid since it caused approximately 50% lowering of the viscosity either at incorporation or after storage for a period of 1 week. The parabens but not benzoic acid could therefore serve as preservatives in formulations containing the polysaccharide gum. The effect of aging on the viscosity of cissus mucilage is presented in figure 6. An increase in viscosity was observed within the first 2 weeks of storage with the viscosity reaching a peak level of 43 cps and thereafter a decrease in resistance to flow was observed. An increase in viscosity of polymeric thickening materials with time is attributed to hydratation effect whereas the phenomenon of a decrease in viscosity of albizia gum disperse system with aging was related to hydrolysis of the polysaccharide gum (2). The present investigation revealed that cissus gum hydrates slowly in aqueous medium. The initial increase in viscosity on storage of the mucilage may be attributed to increase in hydratation with time, which reached a peak level after 2 weeks and thereafter hydrolytic cleavage of the crystal lattice might be responsible for the decline in resistance to flow.

CONCLUSIONS

The new polysaccharide gum exhibits shear thinning effect with thixotropy at concentrations above 4% w/v. The viscosity of the dispersions decreases at temperatures above 30°C. Acid and alkaline pH conditions of < 7 or > 10 could adversely affect the thickening potential of cissus gum. The parabens but not benzoic acid could be employed as preservatives in formulations containing the gum. Thickening effect of the polymer may be enhanced by addition of stabilizers. The indication is that this new polymeric material could be employed as excipient in some liquid pharmaceutical systems. The suspending and emulsifying properties have also been investigated and would constitute separate reports.

Table III. Effect of additives on the viscosity, pH and physical characteristics of 2 % w/v dispersion of cissus gum

	Additive	PH.	Observation	Viscosity (cps) Day 1	Day 7
Nil	Nil	6.3	Nil precipitate		
Methylparaben	0.15 % w/v	6.1	Nil precipitate	14.3	19.1
Ethylparaben	0.05 % w/v	6.1	Nil precipitate	14.3	19.1
Benzoic acid	0.1 % w/v	3.3	Precipitation occurred	7.2	4.8
Ethanol	5 % v/v	6.3	Nil precipitate	14.2	**
Sodium chloride	0.2 % w/v	6.2	Nil precipitate	14.2	**

Fig. 5. Effect of pH on the viscosity of 2% w/v dispersion of cissus gum

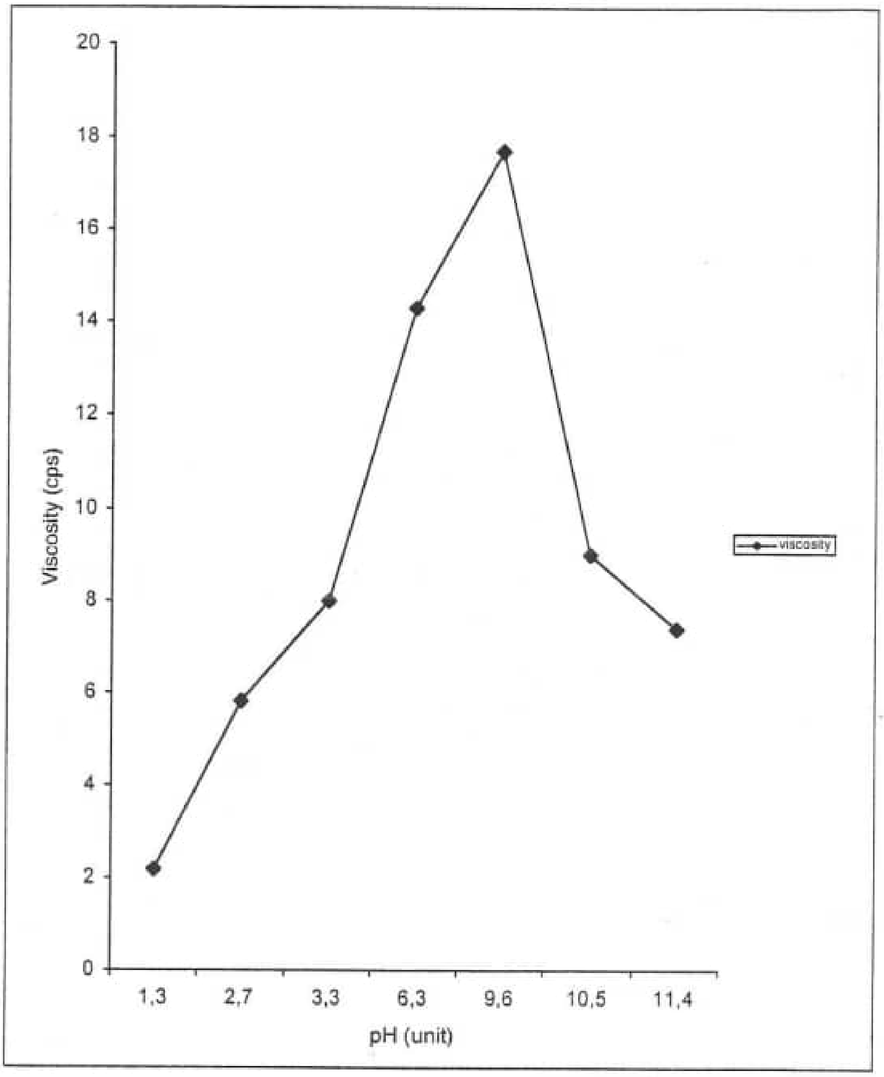
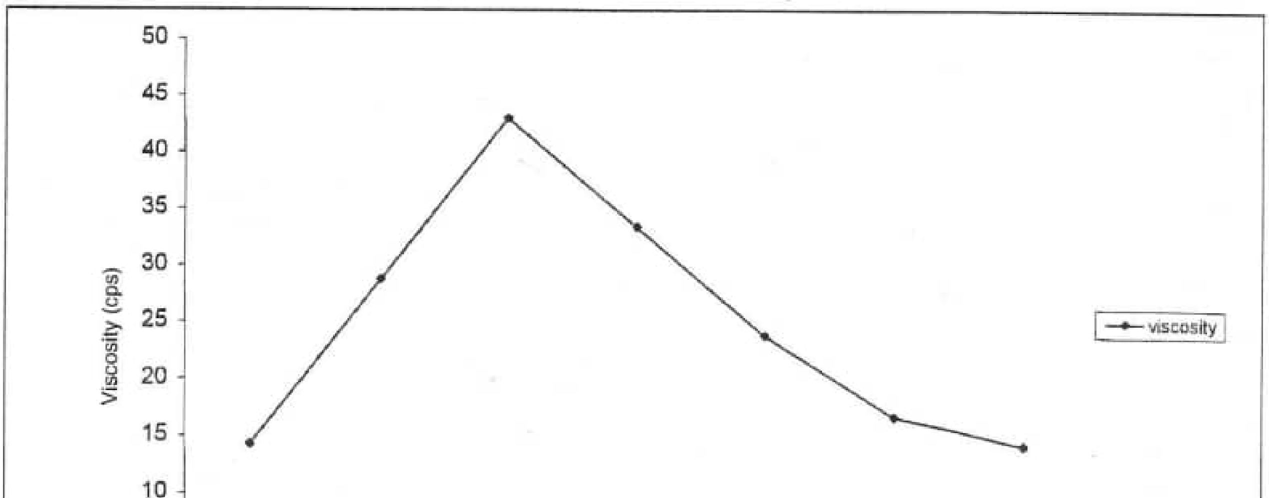


Fig. 6. Effect of aging on the viscosity of 2% w/v dispersion of cissus gum



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