Original Article

Effect of pH on the viscosity of grewia mucilage

Abstract

Background: The stability and efficacy of liquid pharmaceutical preparations depend on the pH of the medium. Such liquid preparations may contain varied additives performing different functions. One of the qualities of oral liquid pharmaceutical preparations is appropriate viscosity for pumping and transfer during manufacture and dispensing to patients. Gums find use in such liquid preparations as thickening or suspending agents together with different additives that may influence the pH of the environment and hence the stability and quality of the preparation. **Aim of the study:** The purpose of this study was to determine the effect of pH on the viscosity of grewia gum obtained from *Grewia mollis* that is potential pharmaceutical excipient. **Setting and Design:** The study was based on experiments carried out in the laboratory setting and the conclusions were based on the observations made. **Materials and Methods:** Aqueous mucilage of grewia (2% w/v) was prepared and the pH was determined at different shear rates on Brookfield cone and plate rheometer at 25°C. Adjustment of pH was facilitated by the addition of 0.25 N solution of either hydrochloric acid or sodium hydroxide before the readings were taken. **Results:** The viscosity of the mucilage was characteristically pseudoplastic and it depended on pH of the medium and storage time. The viscosity ratio generally decreased from 2.046 to 1.470 as the pH of the medium increased from acidic to basic (2.18 to 13.10). The dynamic yield value of the dispersion at pH 2.55 and 5.08 were, respectively, 10.5 and 45. The viscosity of grewia gum dispersion changed with change in pH of the medium anomalously. **Conclusion:** Changes in the viscosity of grewia gum dispersion were observed with change in the pH in an unrelated fashion. This suggests that the use of grewia gum together with other additives in oral liquid preparations should be done with discretion.

Key words:
Effect of pH, grewia mucilage, viscosity

Introduction

Grewia gum is a natural polymer of interest to pharmaceutical scientists.[1-5] The researchers have investigated the suspending,[6] binding,[3] bioadhesive,[4] drug delivery,[7,8] and film coating properties of the gum. The main feature of the gum is the ability to swell and form a gel when in contact with water. The application and use of grewia gum, as with many polymers in pharmaceutical formulations rely on this ability to swell or form gel. One of the most important characteristics of polymers is their ability to form viscous solution in water.[9] Rheological evaluation of gums and mucilage is important because much useful behavioral and predictive information can be obtained.[10-13] It also provides information on the effect of processing, formulation changes, and aging phenomena among others. Moreover, quality by design (QbD) principles make it necessary to establish a design space for pharmaceutical products, active ingredients, excipients, and the unit operations used to produce the finished products and the excipients.[14-16] It has been suggested that rheology is the most sensitive method for material characterization because the flow behavior is responsive to properties such as molecular weight and molecular weight distribution.[17] Rheological measurements are also useful in following the course of a chemical reaction. They allow study of chemical, mechanical

Access this article online	
Website: http://www.cysonline.org	Quick Response Code
DOI: 10.4103/2229-5186.98687	

Ikoni Ogaji, Xiujuan Peng[1], Ignatius S. Okafor, Stephen W. Hoag[1]
Department of Pharmaceutics, Faculty of Pharmaceutical Sciences, University of Jos, PMB 2084 Jos 930003, Nigeria, [1]Department of Pharmaceutical Sciences, School of Pharmacy, University of Maryland, 20 N Pine Street, Baltimore MD 21201, USA

Address for correspondence:
Prof. Stephen W. Hoag,
Department of Pharmaceutical Sciences, School of Pharmacy, University of Maryland, 20 N Pine Street, Baltimore MD 21201, USA.
E-mail: shoag@rx.umaryland.edu

and thermal treatments; effects of additives; or the course of curing reaction. It has also been shown that viscosity may be affected by the pH, ionic strength, and concentration of the solution.[18-23] None of the earlier works addressed the effect of pH and aging on the rheological properties of grewia gum. The aim of this study was to investigate the effect of pH and aging on the rheological properties of aqueous dispersion of grewia gum extracted and purified by the application of heat in the presence of an electrolyte.

Materials and Methods

Sodium hydroxide, sodium chlorideand hydrochloric acid (Spectrum Chemicals, Brunswick, NJ, USA), and grewia gum were obtained from Pankshin Local Government Area, Plateau State, Nigeria.

The extraction method previously described for grewia gum was used to extract the gum[6] Briefly, a 300.0 g grewia gum powder was dispersed in a 2-liter demineralized water (Millipore Corporations, USA) in which a 100.0 g of sodium chloride had been dissolved. The dispersion was subjected to heat on a hot magnetic plate with continuous stirring and the mixture was brought to boil for 30 min. The dispersion was allowed to cool for 24 hr. The sediment was decanted as impurities while the supernatant was centrifuged at 4200 rpm (Allegra 6R centrifuge, Beckman Coulter™, USA) for 10 min to remove impurities. The supernatant containing the gum was then extracted with ethanol 96%. The gum was dried in the oven at 50°C for 24 hr. The sample was kept in sealed polythene bag until required.

A 2% w/v dispersion of grewia was made and the pH of the mucilage was determined on Orion ISE/pH meter (model 720A, Thermo Electron Corporation, MA, USA) at 25°C after the pH meter was calibrated against standard solutions at pH of 4.10, 7.00, and 10.05. The pH of the aqueous dispersion was varied by adding 0.25 N of either sodium hydroxide or hydrochloric acid monohydrate and the system was stabilized with the addition of potassium salts or boric acid buffering agents.[24]

Triplicate 15 ml of 0.70% w/v grewia gum mucilage was transferred to 20 ml plain vials and were adjusted with 0.25 N of either sodium hydroxide or hydrochloric acid. The sample volume in the vials was made up to 17 ml with distilled water, where necessary. The samples were stored in the laboratory at 25°C for 3 weeks and the effect of storage on the viscosities of the samples was monitored on Brookfield rheometer using CP 40 at 20 rpm.

The accuracy of the Brookfield rheometer (DV-III+ model, Brookfield Engineering, USA) was verified using viscosity standard fluids provided by the instrument manufacturer. The gap between the plate and the cone was verified before measurements. The plate was moved up toward the cone until the pin in the center of the cone is 0.0005 inch (0.013 mm) from the surface of the plate. About 2 ml sample of freshly prepared grewia gum (2% w/v) mucilage was transferred to the sample holder and secured in position. The rheological characteristics were determined at shear rates between 75 and 1500 sec^{-1}. All measurements were carried out at controlled temperature of 25°C with the aid of water bath. The results were the average of five determinations. Extrapolation of plots of the relationship between rotational speed and the viscosity was made to zero spindle rotation to give a value on the x-axis that represents the dynamic yield value.

Results

The rheological properties of grewia mucilage

An off white powder of grewia gum was obtained from which the mucilage was prepared. The pH of 2% w/v dispersion of grewia gum was 5.36. [Figure 1] shows the relationship between shear stress and shear rate of the 2% w/v mucilage. At 375 sec^{-1}, the minimum shear stress was 30.7 D/cm^2 and the highest shear stress was 114.3 D/cm^2. The shear stress increased with increase in shear rate, and at the same time the viscosity of the sample decreased with increasing shear rate. The plot of shear stress against shear rate was not linear. [Figure 2] shows the viscosity ratios of the sample at different pH conditions. The values were above 1.0 and ranged between 1.469 (corresponding to pH 13.10) and 2.046 (corresponding to pH 2.18). The viscosity ratio generally decreased with increase in the pH of the mucilage. [Figure 3] shows the relationship between viscosity of the mucilage and the shear rate or spindle rotation speed. At 375 sec^{-1} shear rate, the viscosity of the mucilage at pH 2.18, 2.55, 2.57, and 3.37 were, respectively, 24.2, 8.11, 25.5, and 15.2 cP. The corresponding value at pH 4.12, 4.25, 5.08 and 5.36 were, respectively, 21.8, 15.8, 30.5, and 27.9 cP, while the viscosity values were 14.0 and 13.5 cP, respectively, at pH 12.95 and 13.10. The maximum viscosity of the sample was obtained at pH 5.08 while the minimum viscosity of the sample was observed at pH 2.55. The viscosity was generally of the order: pH 5.08 > 5.36 >>2.57 > 2.18 > 4.12 > 4.25 > 3.37 > 12.95 > 13.10 > 2.55. As the shear rate was increased from 75 to 1500 sec^{-1}, the viscosity of the sample decreased. The figure also shows how viscosity can change as a function of pH and rotational speed or shear rate. At pH 5.08, the viscosity of the mucilage was minimal and the rheological profile resembled Newtonian solution. Generally, the aqueous dispersion of grewia gum displayed pseudoplastic flow behavior. Grewia gum, at the selected pH, showed a general decrease in viscosity with change in pH except at pH 5.08 and these changes were not in any order. An alteration of the gum's pH from pH 5.36 (where the gum is naturally obtained) can cause viscosity change of up to 80% (pH 2.18, 2.57, and 4.12).

Dynamic yield value determination

The dynamic yield values of grewia gum at different pH

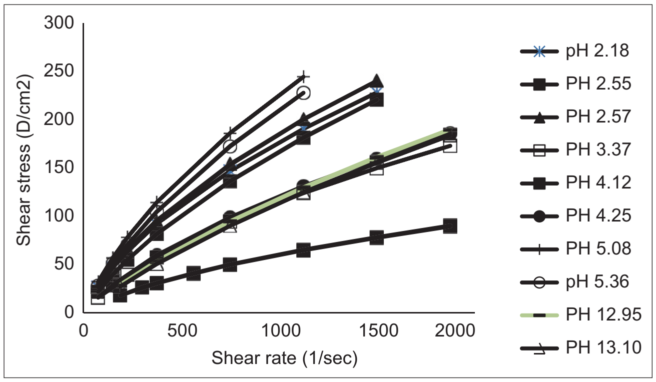

Figure 1: Relationship between shear rate and shear stress of grewia 2% w/v mucilage

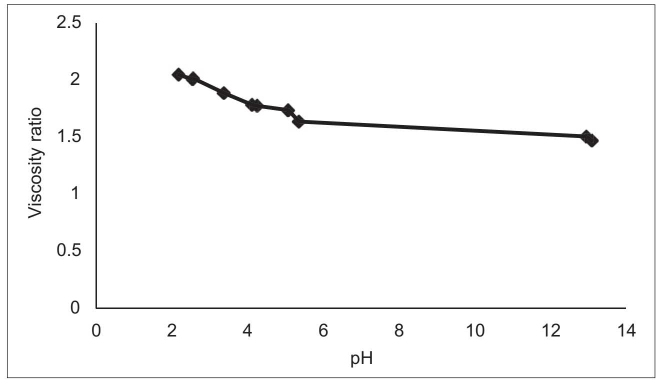

Figure 2: Effect of pH on the viscosity ratio of grewia gum mucilage

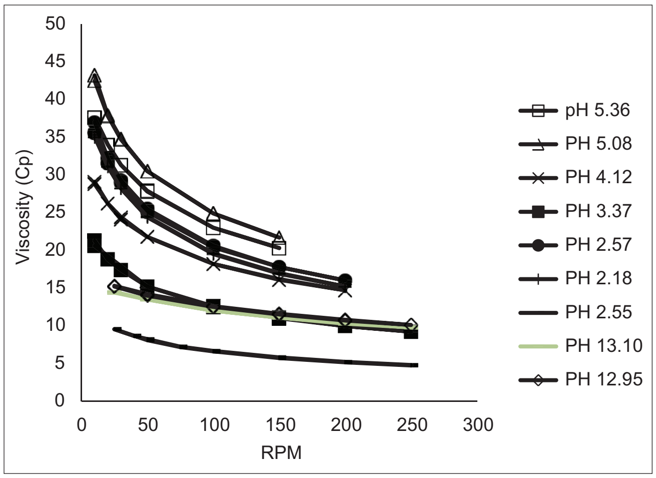

Figure 3: Effect of shear rate/speed on the viscosity of grewia 2% w/v mucilage

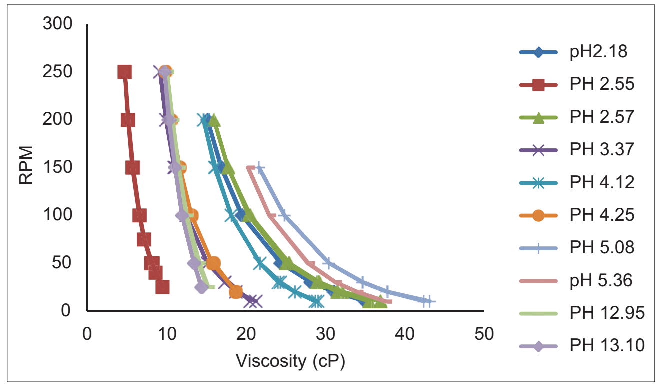

Figure 4: A rheogram of viscosity of grewia gum 2% w/v mucilage versus rpm to determine dynamic yield value

values are shown in [Figure 4]. The increasing order of the dynamic yield value as a function of pH was as follow: pH 2.55 <12.95 <13.10 <4.25 <3.37 <4.12 <2.18 <2.57 <5.36 <5.08. The data showed that the minimum dynamic yield value of the mucilage was 10.5 (obtained on samples at pH 2.55) while the maximum yield value was 45 (obtained on sample at pH 5.08), corresponding to the point of highest viscosity observed.

Effect of storage on the viscosity of grewia mucilage

The effect of storage of the gum is depicted by [Figure 5]. At a given pH value, the viscosity of the gum decreased with storage.

Discussion

The application of heat in the presence of an electrolyte before extracting the gum with ethanol 96 % yielded an off white to whitish powder compared to that described previously.[6] The reliability and reproducibility of the viscosity data obtained were ensured with the use of appropriate buffers that minimized pH during tests.

The measured viscosity of a fluid can be seen to behave in one of four ways:

(a) Viscosity remains constant no matter what the shear rate (Newtonian behavior)
(b) Viscosity decreases as shear rate is increased (shear thinning)
(c) Viscosity increases as the shear rate is increased (shear thickening)
(d) Viscosity appears to be infinite until a certain shear stress is achieved (Bingham plastic behavior).

In rheological studies, the relationship between shear stress and shear rate defines the flow characteristics of the material. Non-Newtonian fluids are encountered in real world, and application of effects of shear rate is very important for practical application of rheological data. Knowledge of the viscosity of a material like grewia gum at various shear rates and pH conditions is very important for processing, formulation, or quality control use. Grewia gum exhibited pseudoplastic shear thinning behavior, and the viscosity decreased as the shear rate increased. There was probably a temporary change in the structure of the mucilage. The mucilage probably orients itself more parallel to the spindle surface, thereby decreasing its resistance to spindle rotation. At faster spindle rotation more molecules

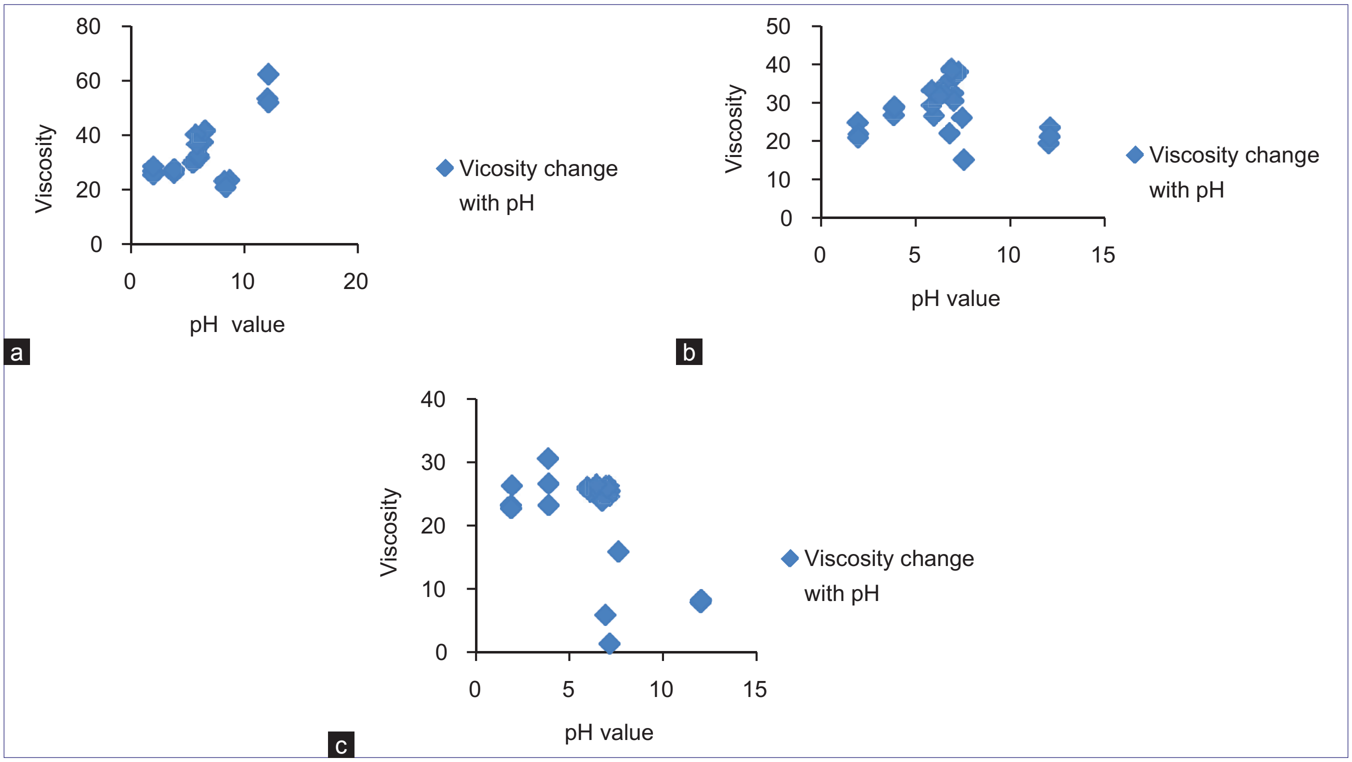

Figure 5: Effect of storage on the viscosity of grewia gum mucilage (a) I week (b) 2 weeks, and (c) 3 weeks

formations are "destroyed" with the result that less of the molecules slide together, leading to low viscosity.[17] Since in non-Newtonian fluids the measured apparent viscosity value is a function of the equipment and the spindle used in their determination, the viscosity ratio has become a very useful and common method for characterizing and quantifying materials of such nature at two different speeds with the same spindle. The viscosity ratio of pseudoplastic shear thinning fluids will exceed 1.0 and the value increases as the degree of pseudoplasticity increases.[17] The viscosity ratios suggested that the pseudoplasticity of grewia gum increased with decrease in pH. This study shows that the effect of pH on the viscosity of grewia gum is anomalous. This knowledge is critical to proper development of a formulation, improvement of formulation, processing, and use of grewia gum mucilage as a novel pharmaceutical excipient. Some fluids behave much like a solid at zero shear rate and they will not flow until a certain amount of force is applied, at which time they will revert to fluid behavior. This force is called the yield value and measuring it is worthwhile particularly that the viscosity of grewia gum is influenced by the pH in a nonlinear fashion. Yield values can help determine whether a pump has sufficient power to start in a flooded system and often correlates well with other properties of emulsions and suspensions.[17] The pourability of a material is directly related to its yield values. They showed that changes in rheological properties of a material on storage may be related to changes in quality of the material. This is important in pumping and processing. Although grewia gum typically exhibited a pseudoplastic flow characteristic around the pH region that it naturally occurs, the flow at pH of 2.55, 12.95, and 13.10 are more like Newtonian. This was probably due to destruction of intermolecular structure and bonding at these pH values and the effect was most pronounced at pH 2.55. Storage plays a very significant role in the stability of grewia gum and it was independent of the pH environment. This knowledge is very important in the design of the shelf life of this material as whole or aqueous preparations in formulations. Grewia mucilage was prepared from grewia gum extracted from the stem bark of *Grewia mollis.* The rheological properties of the mucilage were investigated at different shear rates and pH conditions. Grewia gum exhibited pseudoplastic characteristic that was affected by change in the pH of the system and storage.

References

1. Okafor IS. Characterization and application of grewia gum in tabletting, Pharmaceutics PhD, Nsukka:University of Nigeria; 2001.
2. Okafor IS, Chukwu A, Udeala OK. Some physicochemical properties of grewia gum. Nigeria JPolymSciTechnol2001;2:161-8.
3. Emeje M, Isimi C, Kunle O. Effect of Grewia gum on the mechanical properties of Paracetamol tablet formulations. African J PharmPharmacol2008;2:1-6.
4. Nep EI, Okafor IS. Evaluation of the bioadhesive property of Grewia gum in indomethacin tablet formulation in pig gastric mucus. J PharmBioresources2006;3:62-9.
5. Ogaji I, Okafor IS. The film coating potential of grewia gum: Some physicochemical properties of paziquantel tablets. Int J Pharm Res 2011;3:16-9.
6. Ogaji I, Hoag SW. Effect of grewia gum as a suspending agent on ibuprofen paediatric formulation. AAPS PharmSciTech2011;12:507-13.

7. Okafor IS, Danat IM. The influence of granulating solvents on drug release from tablets containing grewia gum. J PharmBioresources 2004;1 76-83.
8. Nep EI, Conway RB. Polysaccharide gum matrix tablets for oral controlled delivery of cimetidine. J PharmSciRes 2010;2:706-16.
9. Van Der Reijden WA, Verman EC, NieuwAmerongen AV. Rheological properties of commercially available polysaccharides with potential use in saliva substitutes. BioRheology1994;31:631-42.
10. Haug A, Smidsrod O. Determination of intrisic viscosity of alginates. ActaChemScand 1962;16:1569-78.
11. Woolfe ML, Chaplin MF, Otchere G. Studies on the mucilages extracted from okra fruits (Hibiscus esculentus L.) and baobab leaves (Adansoniadigitata L.). JSci Food Agric 1977;28:519-29.
12. XuX , Liu W, Zhang L. Rheological behavior of Aeromonas gum in aqueous solutions. Food Hydrocolloids 2006;20:723-9.
13. Xu X, Xu J, Zhang Y, Zhang L. Rheology of triple helical Lentinan in solution: Steady shear viscosity and dynamic oscillatory behavior. Food Hydrocolloids 2008;22:735-41.
14. ICH. Guidelines for industry Q8 pharmaceutical development, in: U.S.D.f.h.a.h. services (ICH), FDA, CDER, Washington DC: USA 2006.
15. Moreton C. Functionality and performance of excipients in quality by design world part 4: Obtaining information on excipient variability for formulation design space. Amer Pharm Rev 2009;12:28-32.
16. Fu S, Thacker A, Sperger MD, Boni LR, Velankar S, Munson JE, *et al*. Rheological evaluation of inter-grade and inter-batch variability of sodium alginate. AAPS PharmSciTech 2010;11:1662-74.
17. Brookfield, More solutions to sticky problems- a guide to getting more from your Brookfield viscometer, MA, USA: Brookfield Engineering labs Inc;2009.
18. Aktas Z, Woodburn ET. Effect of addition of surface active agent on the viscosity of a high concentration slurry of a low-rank British coal in water. Fuel Processing Technol 2000;62:1-15.
19. Anema SG, Lowe EK, Li Y. Effect of pH on the viscosity of heated reconstituted skim milK. Int Dairy J 2004;14:541-548.
20. George J, McCracken KJ. Effects of acid and alkali concentration on in vitro measurement of wheat viscosity. Animal Feed SciTechnol 2002;98: 237-44.
21. Owen DH, Peters JJ, Lavine ML, Katz DF. Effect of temperature and pH on contraceptive gel viscosity. Contraception 2003;67:57-64.
22. Peleg H, Noble AC. Effect of viscosity, temperature and pH on astringency in cranberry juice. Food QualPrefer 1999;10:343-7.
23. Phelps RA, Cann JR. On the modification of conalbumin by acid. II. Effect of pH and salt concentration on the sedimentation behavior, viscosity and osmotic pressure of conalbumin solutions, ArchBiochem Biophysics 1956;61:51-71.
24. United States Pharmacopoeia 32/ National Formulary 27. Buffer solutions. Vol.1.Rockville, MD, USA:The United States Pharmacopoeia Convention; 2009.p.861-2.

How to cite this article: Ogaji I, Peng X, Okafor IS, Hoag SW. Effect of pH on the viscosity of grewia mucilage. Chron Young Sci 2012;3:141-5

Source of Support: Nil, **Conflict of Interest:** None declared