



Food Hydrocolloids

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The stability of guar gum in an aqueous system under acidic conditions

Q Wang  , P.R Ellis, S.B Ross-Murphy

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Abstract

The stability of guar galactomannan in acidic conditions was investigated using dilute polymer solutions at temperatures of 25, 37 and 50°C. The depolymerisation of guar galactomannan was monitored by determining changes in solution viscosity, from which the viscosity-average molecular weight was estimated. The lowest pH values at which guar galactomannan remained stable were found to be 2.0, 3.0 and 3.5, respectively, at these temperatures. The acid degradation appears to be a random scission process obeying first order kinetics. The activation energy at pH 1.5, 2.0 and 3.0 were estimated to be 117.4, 118.6 and 120.5 kJ mol⁻¹, respectively. This indicates that guar gum is reasonably stable under an acidic environment. The viscosity of fully hydrated guar gum solutions at acidic pH was found to be slightly lower than it was at neutral pH even when no degradation occurred. Current results suggest that guar gum may be used in mild acidic processing conditions, particularly when excessive heat treatment is not used.

Introduction

Guar gum, a galactomannan-rich flour extracted from the seeds of the leguminous plant *Cyamopsis tetragonoloba* (L.) Taub, is widely used as a thickening and stabilizing agents,

in a range of industrial applications (Goldstein, Alter & Seaman, 1973). The study of its solution stability in acidic environment is of considerable importance to those studying its functional properties in food processing and the oil industry, and, more recently, to those interested in the physiological effects of dietary fibre (e.g. its behaviour in the human stomach) (Ellis, Rayment & Wang, 1996). Guar galactomannan and many similar polysaccharides are readily hydrolysed to monosaccharides in strong acidic conditions, such as when mixed with 12M sulphuric acid. However, under more gentle conditions, they may either remain undegraded or be partially hydrolysed to produce a variable mixture of monosaccharides, oligosaccharides and polysaccharides with a broad range of degree of polymerisation. The kinetics of acidic hydrolysis of several polysaccharides was investigated previously (Carpron et al., 1996, Ekström, 1985, Ekström et al., 1983, Hjerde et al., 1994), although galactomannans, such as guar gum, were not included in these studies. Apart from the usual physicochemical conditions, such as temperature, pH and concentration, the degradation rate of polysaccharides is also influenced by the conformation of the molecules, namely, the strandedness (Hjerde et al., 1994). It has been generally accepted that galactomannans exist in solution as random coiled single-stranded chains. For such a conformation, a non-specific degradation (random scission) can be expected, and may be described by the following equation (Tanford, 1961a):

$$\frac{1}{\bar{x}_{w,t}} = \frac{1}{\bar{x}_{w,0}} + kt$$

in which $\bar{x}_{w,0}$ and $\bar{x}_{w,t}$ are the weight-average degree of polymerisation at the beginning of the reaction and at reaction time t , respectively, and k is the reaction constant. This equation implies that the reciprocal of weight-average degree of polymerisation is a linear function of the reaction time.

Degradation is often followed experimentally by determining the molecular weight as a function of time, using light scattering or viscosity (usually by measuring intrinsic viscosity) as the measure of molecular weight. The former gives the weight-average molecular weight (M_w) and the latter gives viscosity-average molecular weight M_v . The magnitude of M_v is between M_w and M_n (the number-average molecular weight) and is usually closer to M_w . In the case of condensation polymers, in which there is no change in reactivity of functional groups with chain length, M_v/M_w and M_v/M_n are constants independent of molecular weight. In this case, the intrinsic viscosity $[\eta]$ can also be used to measure M_w and M_n provided calibration is carried out. However, in the present study, the approximation $M_v \approx M_w$ was made without calibration since the change in molecular weight is more important than its precise value. Since $1/\bar{x}_{w,t} \propto 1/M_w$, then $1/\bar{x}_{w,t}$ is approximately $\propto 1/M_v$, which indicates that in a random scission process the reciprocal of viscosity-average molecular weight should also follow a linear dependence on the degradation time.

The work reported here is an investigation of the stability of guar gum solution at different pH levels at 25, 37 and 50°C. A special device was designed to allow the polymer degradation process to be monitored by determining changes in viscosity. The

present study was not designed to investigate the kinetics of guar gum hydrolysis per se, but the main interest was merely to find out to what extent the viscosity of guar gum solutions will change under various conditions of pH and temperature. This approach allowed the time course of hydrolysis to be followed by measuring the changes in relative viscosity without interrupting the process and also without removing aliquots of the sample from the reaction vessel. On the basis of the information obtained from the above experiments, the hydration kinetics of guar gum solution was then studied under pH conditions where the polymer is stable or readily degraded—the results of this work will be published elsewhere.

Section snippets

Samples and preparations

All experiments were carried out using a commercial food grade guar gum flour M150 (Meyprogat range, Meyhall Chemical Company Ltd, Switzerland). The sample, which was analysed chemically by standard methods described previously (Wang, Ellis, Ross-Murphy & Reid, 1996), was found to contain 93% non-starch polysaccharides including 88% galactomannan, 3.7% protein, 1.2% lipid and 0.6% ash on a dry weight basis. The molecular weight of the sample was estimated as 2.8×10^6 by intrinsic viscosity

Kinetics of acidic degradation

As discussed above, assuming that the degradation reaction of guar gum under acidic conditions is a random scission process, the reciprocal of viscosity-average molecular weight ($1/M_v$) should be linearly related to the reaction time. In other words, the reaction obeys first order kinetics. The reciprocal of viscosity-average molecular weight was plotted against incubation time in Fig. 2, taking the data at a temperature of 50°C, as an example. A good linear relationship was obtained between $1/M_v$

Discussion

The strong linear relationship observed between the reciprocal of average molecular weight and reaction time in all experiments indicates that the degradation of guar galactomannan under acidic condition is random with respect to chain cleavage. This linear relationship has been repeatedly observed for the degradation of polysaccharides with a single-stranded conformation (Hjerde et al., 1994, Rickards et al., 1967). This is also consistent with the assumption that guar galactomannan has a

Conclusions

The current study shows that guar gum is relatively stable under mild acidic conditions. Higher temperatures and lower pHs do reduce the stability of guar gum in solution. The lowest pH at which guar galactomannan remains stable, at temperatures 25, 37 and 50°C, was found to be 2.0, 3.0 and 3.5, respectively. The acid degradation of guar gum is likely to be a random scission process with first order kinetics. Current results suggest that guar gum may have extended uses in acidic systems.

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