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Guar Gum Derivatives. II. Foaming Properties of Hydroxyalkyl Derivatives

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ABSTRACT

Foaming properties of O*-(2-hydroxyalkyl) guar gum derivatives have been studied as a function of degree of molar substitution. The effect of the nature of substituent group and the viscosity of the derivatives on foam generation and its stability have been studied. Stability of foam on the rate of mechanical agitation and other solution properties affecting foam generation have also been discussed.*

INTRODUCTION

Surfactants lower the surface and interfacial tensions of the liquid–gas systems by orienting themselves at the liquid–gas interface according to their hydrophilic–lipophilic character (Kuwamura & Kameyama, 1962; Rosen, 1978). However, the situation becomes more complex in the case of polymeric substances exhibiting foaming properties due to subtleties in characterising solute–solvent interactions. Besides, unlike the simple surfactant molecules, polymeric molecules do not possess any well-defined hydrophilic and lipophilic ends. Some polysaccharides give foams which are stabilised by their high solution viscosity. In solution, it is reported that polysaccharides and their derivatives have their chains oriented at the interface in accordance with their hydrophilic–lipophilic character (Sarkar, 1984).

Because of their foaming and foam-stabilising properties, certain polysaccharides are used in the manufacture of emulsions and foams

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(Dawson, 1981). The foaming properties of such polysaccharides are explained on the basis of nonionic surfactancy. The situation is somewhat similar to the surfactant nature of alkylene oxide adducts of alcohol and phenol containing polyalkoxy chain $R—(O—CH_2—CHR)_n—OH$ where R may be an alkyl radical or hydrogen atom (Rossi & Baldacci, 1951; Kuwamura & Kameyama, 1962). Ethylene oxide adducts are known to foam better than propylene oxide adducts (Matsuda *et al.*, 1969).

When guar gum solutions are stirred vigorously a small amount of foam is produced which is stabilised due to high solution viscosity. Introduction of hydroxyalkyl groups in the guar gum molecule increases foamability of its solutions. This paper is concerned with foaming properties of guar gum and its hydroxyalkyl derivatives as a function of degree of hydroxyalkylation. In our earlier paper (Prabhanjan *et al.*, 1989), other solution properties of hydroxyalkyl and carboxymethyl derivatives of guar gum have been described.

MATERIALS AND METHODS

Guar gum used in this study had the following analysis: moisture, 12·8%; protein, 2·1%; ash, 0·6%; and viscosity, 8000 ± 500 centipoise-seconds (cPs) (Brookfield, 1% solution).

O-(2-Hydroxyethyl) and *O*-(2-hydroxypropyl) derivatives of guar gum (abbreviated as HEG and HPG, respectively) were prepared according to the procedure given in an earlier communication (Prabhanjan *et al.*, 1989).

Foam was generated in solutions by means of mechanical agitation with a Remi mechanical stirrer. The gum was added gradually with gentle stirring to water (200 ml), contained in a polythene jar (radius 3·5 cm, height, 15 cm). After obtaining lump-free and hydrated (4 h) dispersions, the pastes were agitated for 4 min by adjusting the stirring rate to 4000 ± 100 rev/min. The foam height attained was measured immediately after the foam was generated.

Foam stability of gum solutions was measured by two methods; by the rate of collapse of foam in the foamed solution; and by the time taken for the foam to collapse completely to its original unfoamed volume (200 ml).

RESULTS AND DISCUSSION

Foaming properties of hydroxyalkyl guar gum solutions are shown in Fig. 1. It is found that foaming of guar derivatives increases with the

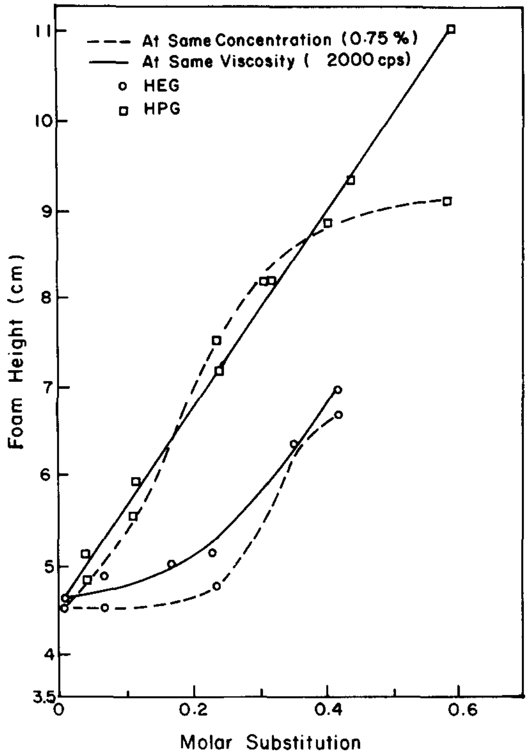

Fig. 1. Effect of molar substitution on foamability of guar gum derivatives.

increasing degree of molar substitution (MS) not only at the same concentration but also at the same viscosity. It is interesting to note that at a viscosity of ~ 2000 cPs the foam height of HPG increases linearly with MS. On the other hand, HEG shows only a curvilinear relationship. As MS increases, it is expected that the hydroxyl groups on the guar chain would undergo polycondensation with the reagent molecule. This probability is increased as the newly generated hydroxyl groups in the substituent group of the derivative would be more reactive compared to the native gum molecule. In other words, the length of the substituent chain would increase with increasing MS with consequent increase in the foaming capacity of the derivative, similar to alkylene oxide adducts of alcohols and phenols (Rossi *et al.*, 1951; Kuwamura *et al.*, 1962). Higher solubility of the polymer is an important parameter in enhancing the foaming capacity of a surfactant. This aspect has been discussed by Rosen (1978). Guar gum gives cold-water, swellable dispersions. However, the dispersions are slightly turbid due to some insoluble portion. Hydroxyalkylation of guar gum, on the other hand, gives products of increasing solubility with increasing MS. At equivalent MS, HPG gums are more soluble than HEG gums (Prabhanjan *et al.*, 1989) and therefore produce more foam.

Sarkar (1984) has studied the interfacial properties of aqueous solutions of methyl and hydroxypropylmethyl celluloses. He observed that the decrease in interfacial tension was directly related to the degree of substitution/molar substitution of substituent groups. Our results (Fig. 1) show that with increasing MS of HE and HP groups, the foaming is increased. Since the foaming is due to lowering of interfacial tension between air and water phases, our results are in conformity with those of Sarkar (1984). The differences in foaming capacity of HEG and HPG is also explainable on the basis of hydrophilic–lipophilic balance (HLB). In both the derivatives, the hydrophilic part is the carbohydrate moiety i.e. hexose units of mannose and galactose whilst the lipophilic part is constituted by substituent groups. Inasmuch as HP groups are more lipophilic due to a greater number of carbon atoms compared to HE groups, the HLB of HPG gums will be less compared to HEG gums and, consequently, the lowering of interfacial tension will be more in the former at all levels of substitutions. Sarkar (1984) has estimated that the HLB of glucose unit of cellulose is 9·9 and that the value is decreased by methyl and hydroxypropylmethyl substituent groups, more by the latter groups because of higher lipophilicity.

Figure 2 shows the effect of gum concentration on the foaming capacity of guar gum derivatives. It is found that, up to a certain concentration of gum derivatives, the foam height increases and thereafter it decreases. An increase in gum concentration results in an increase in solution viscosity. In highly viscous solutions, the introduction of air bubbles by means of mechanical agitation becomes increasingly difficult. However, in general, it is observed that irrespective of the gum concentration at which the gum foams to the maximum, the corresponding viscosity at that concentration of the solution is 2200 ± 300 cPs. The data are given in Table 1.

Stability of foams is an important aspect of certain foam applications. Generally, foam stability is a measure of retention of lamellar structure and reduction in drainage of liquid between the lamellae (Bikerman, 1973). Figure 3 shows the stability of foams, produced by hydroxyalkyl gums, as measured by the rate of foam collapse. For studying the foam stability of hydroxyalkyl derivatives, those concentrations were used at which maximum foaming was observed. It is found that HPGs having MS between 0·2 and 0·3 have maximum foam stability. In general the HEGs have lower foam stabilities.

Prins (1976) has studied the effect of mechanical agitation of a surfactant solution on foam formation. He has found that foaming

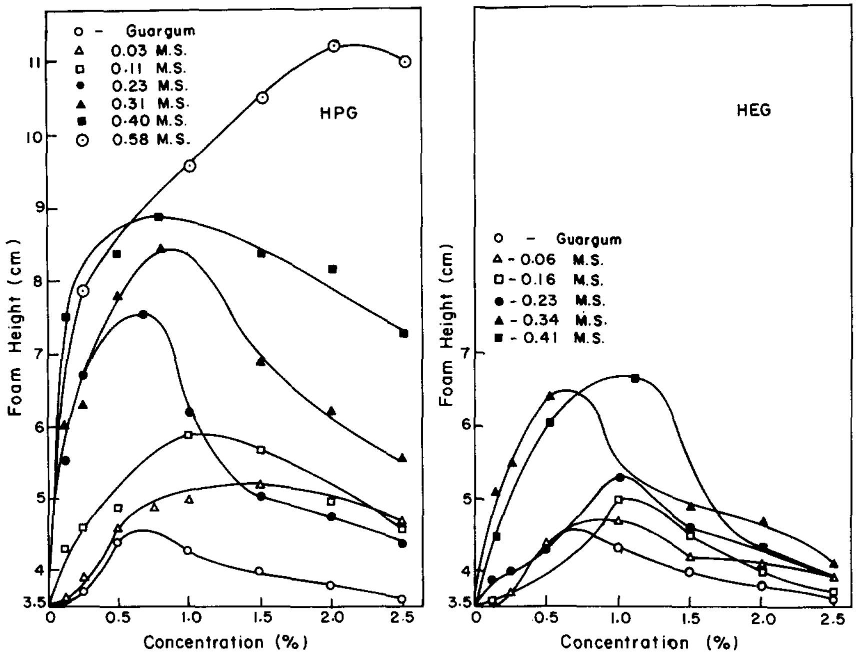

Fig. 2. Effect of concentration on foamability of hydroxypropyl and hydroxyethyl guar gums.

TABLE 1
Viscosity Values of Gums and the Concentration at which they Foam to Maximum Extent

Guar gum/ derivative	*MS*	*% Concentration at which maximum foaming obtained*	*Foam height (cm)*	*Corresponding viscosity (cPs)*
Guar gum	—	0·7	4·5	2280
HPG	0·03	1·3	5·3	2000
HPG	0·11	1·0	5·9	2300
HPG	0·23	0·8	7·5	2200
HPG	0·31	0·9	8·4	2480
HPG	0·40	0·9	8·9	2440
HPG	0·58	1·8	11·4	3500
HEG	0·06	1·0	4·7	1700
HEG	0·16	1·0	5·0	2100
HEG	0·23	1·0	5·3	2700
HEG	0·34	0·8	6·6	2400
HEG	0·41	1·3	7·0	2520

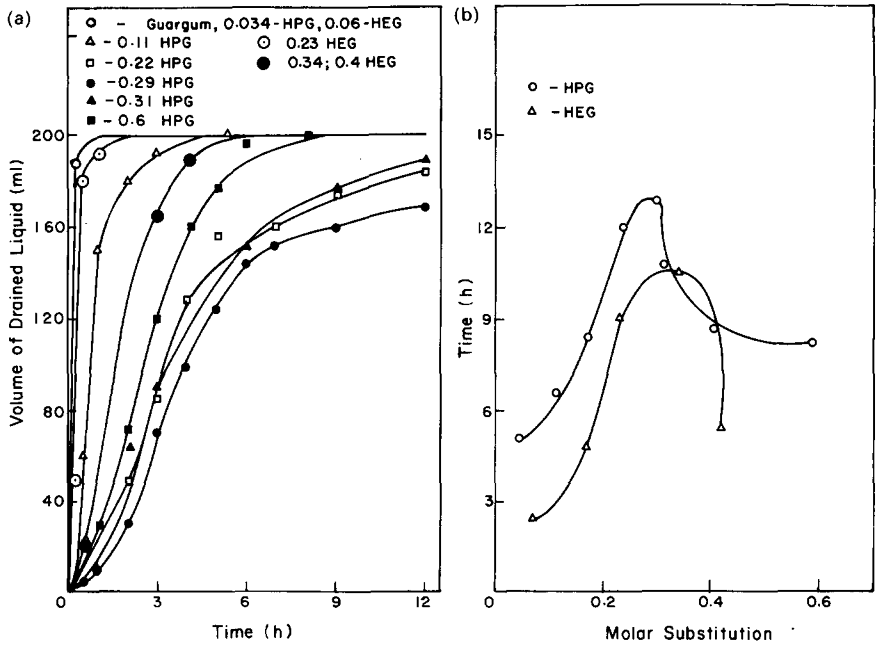

Fig. 3. (a) Rate of drainage of liquid from foams of hydroxyalkyl guar gums. (b) Effect of molar substitution on foam stability (time (h) for complete collapse of foam) of hydroxyalkyl guar gums.

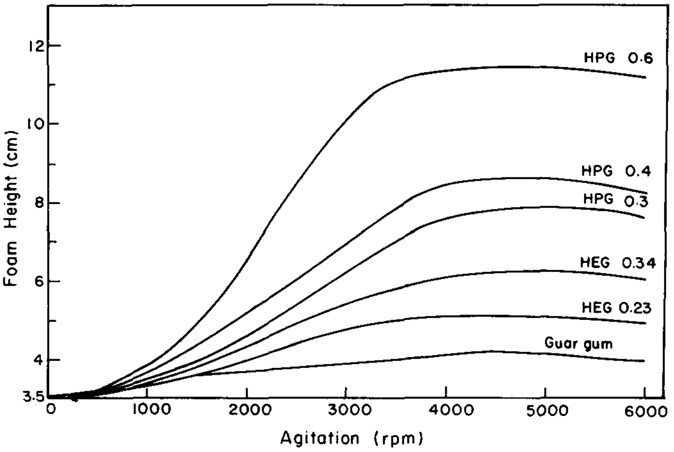

Fig. 4. Effect of mechanical agitation on foam height of hydroxyalkyl guar gums.

increases with the rate of agitation (rev/min of the stirrer) but high mechanical agitation has a destabilising effect on the foam already generated and the foam height decreases. The effect of mechanical agitation on foaming of solutions of HEG and HPG is shown in Fig. 4. It is observed that with increasing agitation the foam height increases and beyond a certain rate of agitation (3500–4500 rev/min) a plateau of foam height is obtained. Contrary to the behaviour of conventional surfactant solutions, there is no appreciable drop in the foam height at least up to a stirrer speed of 6000 rev/min. High viscosity of the gum solutions appears to be responsible for foam stability. Another notable observation is that with increasing degree of hydroxyalkylation, especially in the case of HPG, the rate of foam formation increases with the rate of agitation.

CONCLUSIONS

At the same level of modification, hydroxypropylation of guar gum gives products with better foaming and foam stability properties compared to hydroxyethylation. The foamability of HEG and HPG increases with the degree of modification. Similarly, foaming of these gums increases with concentration of the gum in solution but beyond a certain optimum concentration the foamability decreases. An MS of 0·2–0·3 appears to give an HPG of the highest foam stability.

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