

# INFLUENCE OF POLYETHYLENGLYCOL ON RHEOLOGICAL PROPERTIES OF AGAR GEL

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## ABSTRACT

By using of coaxial cylindrical viscosimeter the influence of polyethylenglycol on agar gel viscosity and yield stress has been investigated. The mentioned rheological properties of 1% agar gel is sufficiently influenced only by polyethylenglycol with molecular mass 1500. There are observed maxima in dependences of agar gel rheological properties on polyethylenglycol concentration. The observed regularities can be explained by size effect.

**Key words:** agar gel, rheology, yield stress, least Newtonian viscosity, polyethylenglycol, coaxial cylindrical viscosimeter

## POLİETİLENQLİKOLUN AÇAR GELİNİN REOLOJİ XASSƏLƏRİNƏ TƏSİRİ

### XÜLASƏ

İşdə koaksial silindrik viskozimetrin köməyi ilə polietilenqlikolun agar gelinin özlülüyünə və axının astana gərginliyinə təsiri öyrənilmişdir. 1%-li agar gelinin göstərilən reoloji xassələrinə yalnız molekul çəkisi 1500 olan polietilenqlikol (PEG-1500) əhəmiyyətli dərəcədə təsir edir. Agar gelinin reoloji xassələrinin polietilenqlikolun konsentrasiyasından asılılığında maksimum müşahidə olunur. Alınan qanunauyğunluqlar ölçü effekti ilə izah olunur.

**Açar sözlər:** aqar geli, reologiya, axmanın astana gərginliyi, ən kiçik nyuton özlülüyü, polietilenqlikol, koaksial silindrik viskozimetr

## 1. Introduction

As well as known, some polysaccharides (gelatin, alginate, agar etc.) forms gel state in water [2,9]. At present, hydrogels of polysaccharides are widely used for various purposes due to unique combination of viscose and elastic properties in these materials. It should be especially emphasized its' application in food industry, pharmaceuticals, biomedicine, bioengineering, because they are very tolerated by human organism [4,10,11]. Furthermore, the gel-forming polysaccharides successfully can be utilized in ceramic and nanotechnology [1]. For utilizing of gel in each of these cases the

definite set of rheological data are required. For purposeful controlling of these rheological properties various additives (inorganic salts, micro- and nanoparticles etc.) are introduced to gel medium. In this work the possibility of regulating of gel rheology parameters by adding of other polymer is experimentally investigated.

## 2. Experiment

As a gelator (gel-forming polymer) has been chosen the well known polysaccharide agar (produced by Hispanagar). The basic unit of agar is termed agarobios and consist of alternating 1,3-linked  $\beta$ -D-galactopyra-

nose and 1, 4-linked 3, 6-anhydro -  $\alpha$  - L-galactopyranose (Fig. 1, a). Agar can be fractionated into two components: the higher gel-forming neutral component – agarose and charged component – agaropectin.

The physico-chemical properties of gel are very responsive to preparation technology. In order to obtain reproducible results the preparation has been conducted by standard technology. Initially dry agar is added to distilled water and is kept 24 hours at room temperature for swelling. Then the vessel containing swollen agar is

kept in boiling water for 5 minutes. As a result the homogeneous solution is obtained, in which agar molecules have the random coil conformation (sol state). After cooling below 35 – 40 °C the solution loses its fluidity because of transition to gel state. The obtained gel is kept for a long time (24 hours) to achieve thermodynamically stable state providing the reproducibility of measurements.

As a non-gel-forming polymer (regulator) polyethyleneglycol (PEG) with molecular masses of 300, 600, 1500, 3000 and 6000 has been taken (Fig. 1b).

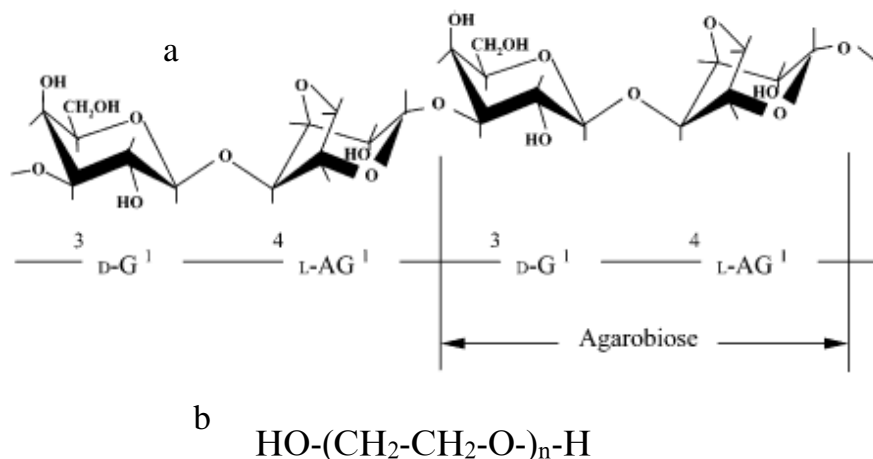


Figure 1.

The measurements were carried out in coaxial cylindrical (or rotational) viscosimeter that allows to build up the dependence of shear rate on stress applied to gel. This dependence is termed as flow curve and plays an important role for rheological characterization of complex fluids [3]. Some rheological parameters of gel (the yield stress, structural viscosity, least Newtonian viscosity) are extracted from this curve.

The applied stress is created by discrete set of loads and is determined by expression

$$\sigma = \frac{mg}{2\pi R_1 h} \quad (1)$$

$mg$  – mass of load,  $R_1$  and  $h$  – radius and height of inner cylinder, respectively.

The rotation of inner cylinder creates a shear deformation. The expression

$$\dot{\gamma} = \frac{d\gamma}{dt} = \frac{\varphi R_1}{(R_2 - R_1)t} \quad (2)$$

is termed as shear rate ( $R_2$  – radius of outer cylinder,  $\varphi$  – rotational angle during the time interval  $t$ ).

### 3. Results

The typical form of flow curve is shown in Fig. 2, indicating the Bingham behaviour of agar gel. Note that Bingham fluids obey the law

$$\sigma = \sigma_0 + \eta_p \cdot \dot{\gamma} \quad (3)$$

where  $\sigma_0$  and  $\eta_p$  are called yield stress and plastic viscosity, respectively.

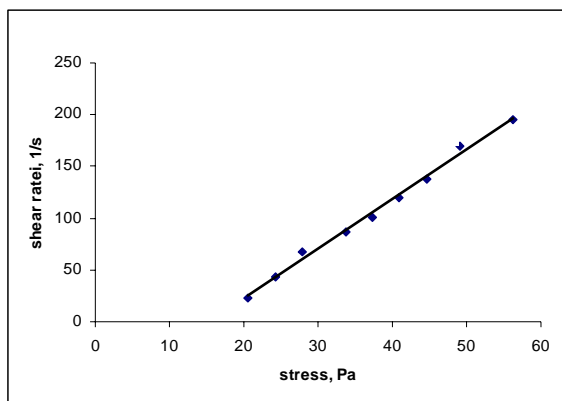


Figure 2

The relation

$$\eta = \frac{\sigma}{\dot{\gamma}} \quad (4)$$

is called an apprence or structural viscosity. Fig.3 presens the dependence of sructural viscosity on shear stress. For sufficiently high stresses it tends (approaches) to constant value ( $\eta_{\infty}$ ) termed as lowest Newtonian viscosity.

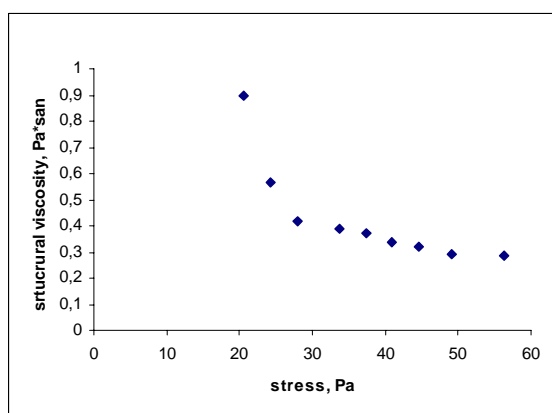


Figure 3

Yield stress and as lowest Newtonian viscosity are important rheological parameters in a sence of practical applications of gels. This work is dedicated to study the influence of polyethylenglycol on these parameters.

Initially the molecular mass of polyethylenglycol has been varied ( $M_w=300, 600, 1500, 3000, 6000$ ). The results of measurements are shown in the Table 1 indicating, that the values of above mentioned rheolo-

gocal parameters are influenced only in the case of  $M_w=1500$  (PEG-1500).

Furthermore, the dependence of yield stress ( $\sigma_0$ ) and least Newtonian viscosity ( $\eta_{\infty}$ ) on polymer (PEG-1500) concentration (Fig.4 and Fig.5) have non-monotonical character.

The observed regularities can be explained on the base of size and conformational considerations.

Table 1.

Gel composition	$\sigma_0, Pa$	$\eta_{\infty}, Pa \cdot s$
1% agar gel	17	0.28
1% agar gel +1%PEG-300	16	0.18
1% agar gel +1%PEG-600	15.5	0.17
1% agar gel +1%PEG-1500	28	0.34
1% agar gel +1%PEG-3000	19	0.22
1% agar gel +1%PEG-6000	16	0.2

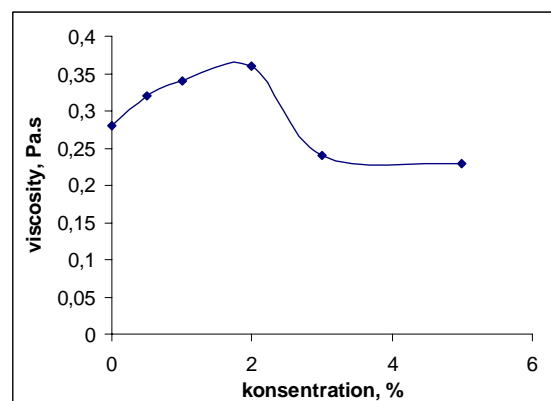


Figure 4

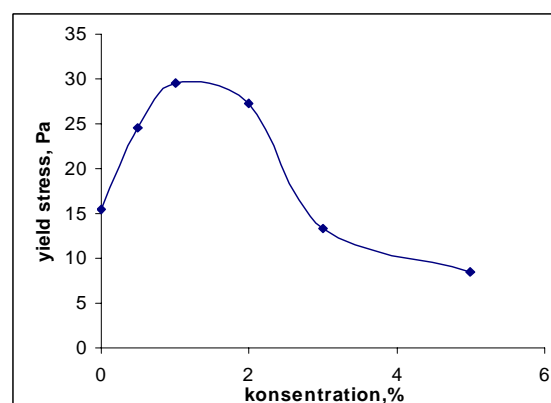


Figure 5

#### 4. Discussions

Agar gel is a thermoreversible physical gel and can be described by crosslinked network model. In according with this model at high temperatures (close to boiling temperature of water) agar molecules take on a random coil conformation and are homogeneously distributed over all volume of solution. The turbid gel occurs by cooling of transparent solution (sol) bellow the temperature  $T_{gel}$  termed the gelation temperature or gel point. The basic structural elements of agar gel network are double helices and their associates termed suprafibers. The formation and crosslinking of these associates arises due to hydrogen bonding with the water molecules.

Gel doesn't flow because of immobilizing of solvent molecules within the cells of gel network. The flowing of gel requires the breaking of network crosslinks that is possible when the shear stress applied to gel precedes some value termed yield stress. It is not difficult believe that yield stress depends on number and energy of links between associates.

Agar gel viscosity depends on number and size of associates. These associates also break into small particles during gel flowing. The higher shear stress the smaller the size of these particles. So the structural viscosity must be decreased by increasing of shear stress that is confirmed by experimental data (Fig.3). The breaking of associates ceases when lowest Newtonian viscosity is achieved.

The reason of strong influence of PEG-1500 on agar gel properties, we suggest, is that the polymer chain length of PEG-1500 is comparable with size of associates (or agar gel pore size). The static light scattering experiments [6, 7] gives 100 nm for size of these associates that have the same order with counter length of PEG-1500 molecules.

Maxima in concentration dependences (Fig. 4,5) are connected with conformational changes by changing of polyethyleneglycol concentration. For high concentrations polyethyleneglycol molecules take on the form of rigid globular spheres and do not affect on gel rheology properties.

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