# ТЕХНОЛОГІЯ ХАРЧОВОЇ ТА ЛЕГКОЇ ПРОМИСЛОВОСТІ

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## RHEOLOGICAL CHARACTERISTICS OF WATER SOLUTIONS OF GUAR GUM

*Rheological characteristics of water solutions of guar gum are studied. Mayonnaise is an oil-in-water type emulsion consisting of vegetable oil (50-85%), egg yolk (5-10%), vinegar, salt and seasonings. The emulsion is stabilized by egg yolk phospholipids. Products with a lower content of oil (<50%) may content thickening agents such as starch, pectin, agar-agar, carboxymethylcellulose, milk proteins.*

*Wide possibilities for using guar gum exist in the mayonnaise technology. Stability at low pH values and low salt content, high viscosity solutions at low shear rate and pseudoplastic characteristics make attractive using systems for stabilization. Because of pseudoplastic characteristics, that are inherent to guar gum, the solutions have fluidity and at the same time stay on salads. Low concentrations of guar gum provide high viscosity of sauces at acidic and neutral pH values. Viscosity of solutions is also stable to temperature changes and withstands different long-term storage conditions. Guar gum may be used for partial replacement of starch, stability improvement and adding a feeling of fullness in the mouth. It is established that growth of concentration of guar gum in an aqueous solution causes gradual increase of the flow index. It should also be mentioned that flow index values are lower than one for all the concentrations, it is typical for pseudoplastic solutions.*

*Results of researches show that guar gum aqueous solutions in a wide range of concentrations refer to Non-Newtonian fluids. It is also defined that the dependence of the stress of the almost destroyed system of guar gum aqueous solutions has a similar shape with the dependence for xanthan gum. Also they have similar absolute values of stresses.*

*When values of the shear stress exceed values of the stress of the almost destroyed system, it is characterized by the lowest values of viscosity. Rheological properties of guar gum aqueous solutions are important for understanding the processes of structure formation that occur. The results obtained may be used in modeling stabilization systems for production of low-fat mayonnaises and sauses.*

***Key words:*** *stabilization, guar gum, galactomannan, rheological properties, viscosity, structure.*

**Problem statement.** For solving the problem of stability of low- and medium-calorie mayonnaises, and sauces, and also for removing from the recipes components that content cholesterol, different nutritional supplements are widely used. At the same time, in spite of the large quantity of already developed foreign supplements, their composition is still unknown for domestic manufacturers of mayonnaise products. Therefore, studies of available and safe vegetable supplements for mayonnaise will allow us to create high quality mayonnaise products and to increase competitiveness of domestic food industry. Thus, research of the rheological properties of solutions of guar gum is an urgent task, solving of which will help in developing of modern high-technological stabilizing systems for mayonnaise production.

**Analysis of recent research.** Hydrocolloids, actions of which are explained by the formation of three-dimensional mesh structure and are accompanied by increasing of the aqueous phase viscosity, are the most effective for structure formation and stabilization of oil-in-water type emulsions. By chemical structure most hydrocolloids are polysaccharides that, depending on the structural composition, are divided

into homopolysaccharides (homoglycans), which are constructed of the same kind of monosaccharide, and heteropolysaccharides (heteroglycans), which consist of different monosaccharides [1].

Nowadays among herbal supplements for improving mayonnaise structure became very popular gum, especially guar gum, xanthan gum and carob gum [2; 3]. By chemical structure xanthan, guar and carob gums belong to a class of neutral polysaccharides. Chemically supplements of this group are polymeric compounds (mostly of polysaccharide nature), macromolecules of which have uniform distribution of hydrophilic groups [4].

Size and form of parts, specific surface, granulometric composition also influence solubility and dispergating of hydrocolloids. Important factors are way of solution preparing (dispersion), intensity and time of mixing, temperature, pH value of environment, presence of electrolytes, mineral substances and substances that are hydrated (e.g. sugar), possibility of forming complexes with other compounds of the system, and decomposition processes caused by action of enzymes or microorganisms [6; 7]. Substances, that can form associates with other macromolecular components of food products, what provoke a significant increase in viscosity and concentration of salt, are known.

**Setting objectives.** Guar gum (cod E412), contained in seeds of the guar pod (Cyamopsis tetragonolobus), belongs to galactomannans (polysaccharides that consist of (1,4)- b – glycosidic linked mannose residues, to which with 1,6- bonds at regular intervals attached side chains, that consist of single residues of α-D- galactose) [5].

Rheological characteristics were determined using a rotational viscometer "Reotest – 2".

**Research results.** Aqueous solutions of guar gum with concentration 0,1–1,0 wt% were used for study of rheological properties. Temperature of the study was 25 C. Obtained rheograms for guar gum solutions are shown in Fig. 1.

It is established that if guar gum concentration is less than 0,3%, then dependence of strain rate on shear stress has almost linear dependence, it indicates that these solutions are Newtonian fluids. Increase of guar gum concentration to more than 0,3 wt% causes changes of rheological behaviour of the solutions. Therefore, when concentration is more than 0,3 wt%, dependence of strain rate on shear stress is described by nonlinear dependence, i.e. in this case aqueous solutions of guar gum refer to non-Newtonian fluids. It should be noted that increase of guar gum concentration causes increase of shear stress, which should be put for providing the same strain rate. Such behaviour of aqueous solutions can be explained by absence or low strength of spatial structure, which is formed by gum molecules at low concentrations. Increase of concentration causes strengthening of the spatial structure, and, as a result of it, liquid acquires non-Newtonian properties.

Values of stresses of almost indestructible system and stresses of almost destroyed system are determined on basis of the obtained results, using graphical method of rheogram analysis. Dependence of stresses of almost indestructible system on guar gum concentration is shown in Fig. 2.

It is established that dependence of stresses of almost destroyed system by type is close to the corresponding dependence of xanthan gum. Dependence in Fig. 2 can be roughly divided into three main areas. In the first area at concentration 0,1–0,5% stress of

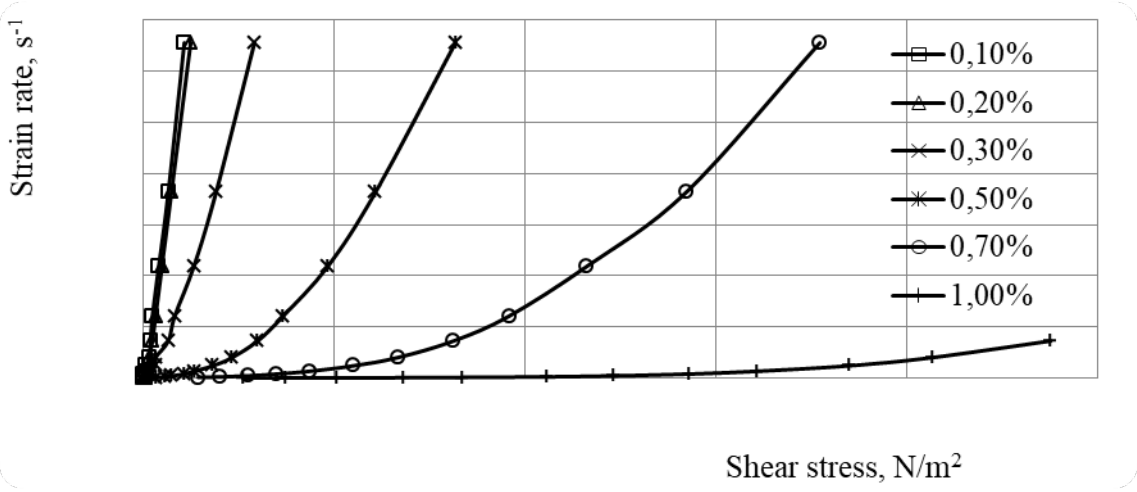


**Fig. 1. Dependence of strain rate on shear stress for aqueous solutions of guar gum at different concentration**

almost indestructible system gradually increases with increase of guar gum concentration. In the second area, which is characterized by 0,5–0,7% concentration, stress sharply increases in almost 5 times.

Further increase of concentration in the third area from 0,7% to 1% causes further slight increase of stress of the system. It should be noted that similar dependence also characterizes behaviour of xanthan gum, but there is a difference that in absolute values of stresses of xanthan gum are almost twice higher than stresses of guar gum.

It should also be noted that in xanthan gum at concentration 0,5% b–0,7% sharp increase of stress in the system is also observed, but this increase is only in 3 times, at the same time, for guar gum it increases in 5 times. For the flow mode, when the stresses are lower than stresses of almost indestructible system, the flow passes with maximum viscosity, dependence of which on guar gum concentration is shown in Fig. 3.

By the results of the conducted research (Fig. 3) it is determined that the viscosity of almost indestructible system for aqueous solutions of guar gum stays almost stable for concentration range 0,1–0,7% and is ~9,0–9,5 mPa·s.

Higher increase of concentration causes sharp increase of viscosity of the system to ~19 mPa·s,

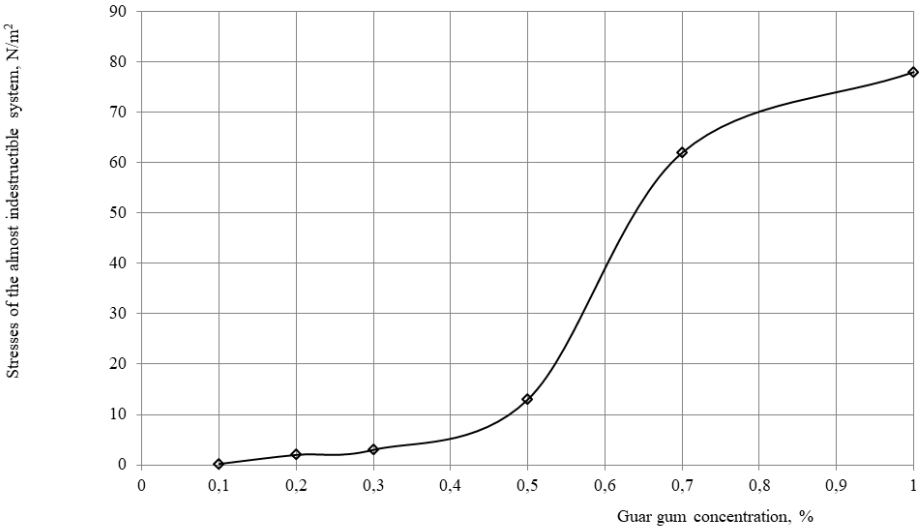


**Fig. 2. Dependence of stresses of the almost indestructible system on guar gum concentration**

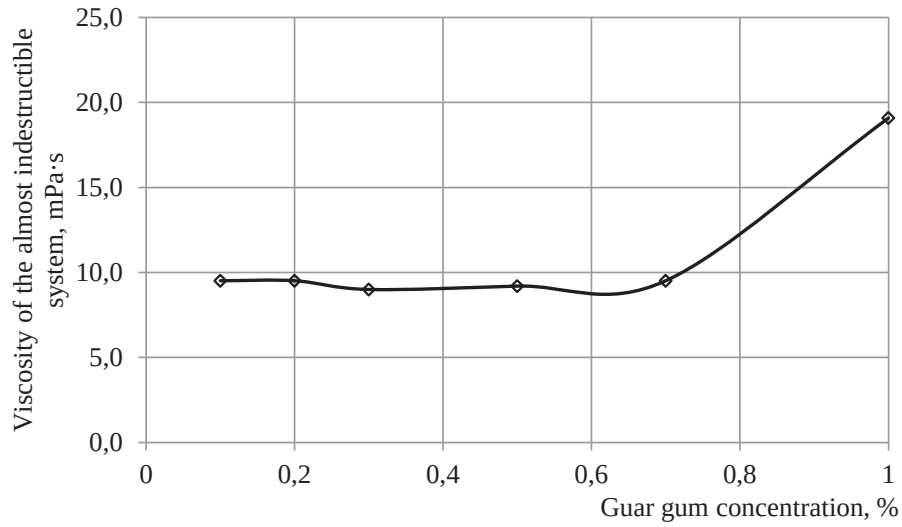


**Fig. 3. Dependence of viscosity of the almost indestructible system on guar gum concentration**

more than in two times. This explains why at concentration higher than 0,7% the system changes from pseudoplastic structure to plastic and in the solution begins to form strong spatial grid.

It should also be mentioned that viscosities of guar gum aqueous solutions have similar values with corresponding values for xanthan gum, but viscosity of xanthan gum constantly increases with increasing of solutions concentration.

The growth of shear stress causes destruction of structures that are formed inside an aqueous solution of polymers. This state is characterized by the stress of the almost destroyed system, dependence of which on concentration is shown in Fig. 4.

As it is seen in the Fig. 4, the stress of the almost destroyed system grows with increasing of guar gum concentration. At the same time, speed of the stress growth increases with increasing of the concentration. First, when guar gum concentration grows from 0,1% to 0,5%, the stress increases from 2,7 N/m$^2$ to 64 N/m$^2$ (for almost 60 N/m$^2$). Next, when concentration grows from 0,7 % to 1,0 %, it causes an increase of the stress for 140 N/m$^2$ from 190 N/m$^2$ to 330 N/m$^2$, i. e. speed of the stress growth increases almost twice. It should also be mentioned that represented dependence, with correlation coefficient 0,98, is described by quadratic dependence.

It is also defined that the dependence of the stress of the almost destroyed system of guar gum aqueous solutions has a similar shape with the dependence for xanthan gum. Also they have similar absolute values of stresses.

When values of the shear stress exceed values of the stress of the almost destroyed system, it is characterized

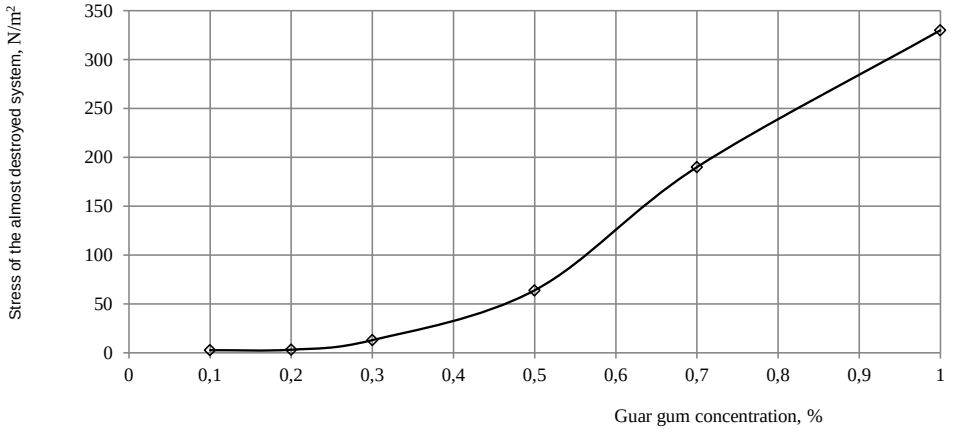


**Fig. 4. Dependence of the stress of the almost destroyed system on guar gum concentration**

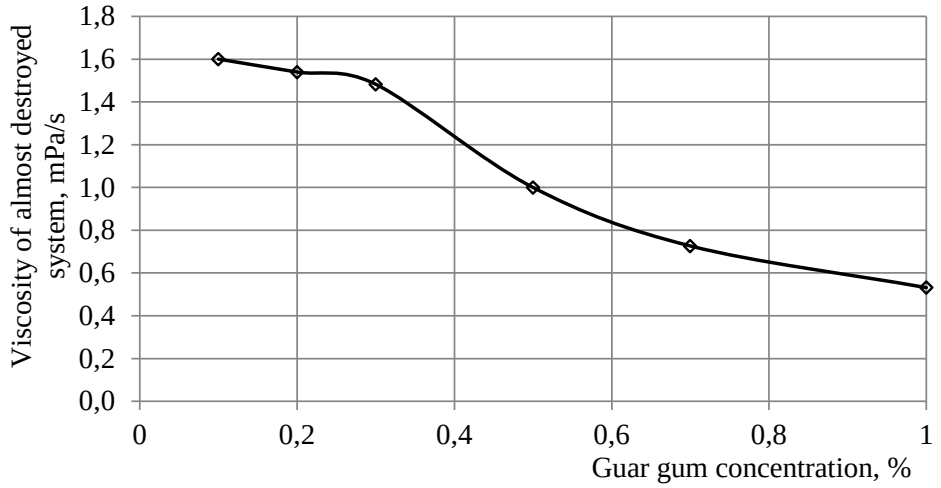


**Fig. 5. Dependence of viscosity of the almost destroyed system on guar gum concentration**

by the lowest values of viscosity. This viscosity is called viscosity of the almost destroyed system, and its dependence on guar gum concentration is shown in Fig. 5.

It is established (Fig. 5) that with increase of guar gum concentration, viscosity of the almost destroyed system decreases. Dependence of this parameter on concentration can be roughly divided into two areas: the first one is from the concentration value 0,1% to 0,3%, and the second one is from 0,3% to 1,0%. The first area is characterized by a gradual insignificant decrease of the viscosity, in this area viscosity of the almost destroyed system decreases by ~0,12 mPa·s from 1,6 mPa·s to 1,48 mPa·s. Transition to the second area provokes a much sharper decrease of viscosity. So the transition of the concentration from 0,3 % to 0,5 % provokes decrease of viscosity for 0,48 mPa·s, what is 4 times more than at the transition from 0,1% to 0,3%.

Besides the graphical method of the obtained dependencies analysis, also was used an analytical method, for realization of which first were built dependencies on the coordinates $\ln P - \ln \gamma$, which are shown in Fig. 6.

It is established that dependence of experimental data on the coordinates has linear character; also the thixotropy parameter and the flow index (deviations from Newtonian flow) are calculated. Results of calculations are shown on the table 1.

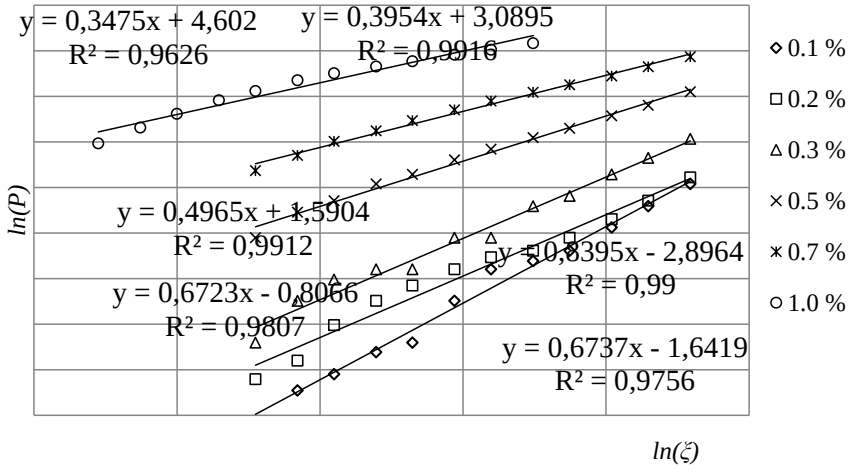


**Fig. 6. Dependence of strain rate on the shear stress in the coordinates $\ln P - \ln \gamma$ for aqueous solutions of guar gum at different concentrations**

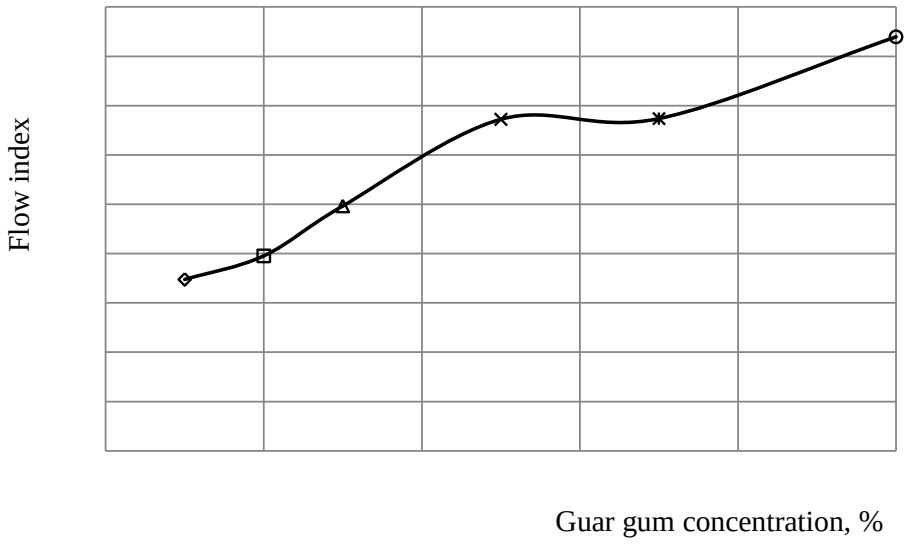


**Fig. 7. Dependence of the flow index of guar gum aqueous solutions on concentration**

Table 1

**Values of the flow index and the thixotropy parameter of guar gum aqueous solutions at different concentrations**

| Guar gum concentration, % | Flow index, *n* | Thixotropy parameter, *σ* |
|---|---|---|
| 0,1 | 0,3475 | 0,010 |
| 0,2 | 0,3954 | 0,046 |
| 0,3 | 0,4965 | 0,204 |
| 0,5 | 0,6723 | 2,240 |
| 0,7 | 0,6737 | 5,165 |
| 1,0 | 0,8395 | 18,109 |

It is defined that with increase of guar gum concentration, the flow index and the thixotropy parameter constantly grow. Dependence of the flow index of aqueous solutions of guar gum on its concentration is shown in Fig. 7.

It is established that growth of concentration of guar gum in an aqueous solution causes gradual increase of the flow index. It should also be mentioned that flow index values are lower than one for all the concentrations, it is typical for pseudoplastic solutions.

**Conclusions.** Results of researches show that guar gum aqueous solutions in a wide range of concentrations refer to Non-Newtonian fluids. Defined rheological properties of guar gum aqueous solutions are important for understanding the processes of structure formation that occur. Obtained results of researches can be used in stabilizing systems modelling using galactomannans for the production of low fat mayonnaises and sauces.

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**Бахмач В.О., Вовкодав О.В., Вовкодав Н.І. РЕОЛОГІЧНІ ХАРАКТЕРИСТИКИ ВОДНИХ РОЗЧИНІВ КАМЕДІ ГУАРИ**

*Досліджено реологічні характеристики водних розчинів гуарової камеді. Майонез – це емульсія олійно-водного типу, що складається з рослинної олії (50-85%), яєчного жовтка (5-10%), оцту, солі та приправ. Емульсія стабілізується фосфоліпідами яєчного жовтка. Продукти з меншим вмістом олії (до 50%) можуть містити загусники, такі як крохмаль, пектин, агар-агар, карбоксиметилцелюлоза, молочні білки.*

*У технології майонезу є широкі можливості використання гуарової камеді. Стабільність за низьких значень pH та низького вмісту солі, розчини з високою в'язкістю за незначної швидкості зсуву та псевдопластичні характеристики роблять привабливим використання стабілізаційних систем. Через псевдопластичні характеристики, що властиві гуаровій камеді, розчини мають текучість і одночасно залишаються на салатах. Низькі концентрації гуарової камеді забезпечують високу в'язкість соусів за кислотних і нейтральних значень pH. В'язкість розчинів також стабільна до перепадів температури й витримує різні умови тривалого зберігання. Гуарова камедь може використовуватися для часткової заміни крохмалю, поліпшення стійкості та додавання відчуття наповненості в роті. Встановлено, що зростання концентрації гуарової камеді у водному розчині зумовлює поступове збільшення показника потоку. Слід також зазначити, що значення індексу потоку нижче, ніж одне для всіх концентрацій, це характерно для псевдопластичних розчинів. Результати досліджень показують, що водні розчини гуарової камеді в широкому діапазоні концентрацій належать до неньютонових рідин. Також визначено, що залежність напруги майже зруйнованої системи водних розчинів гуарової камеді має аналогічну форму із залежністю для ксантанової камеді. Також вони мають аналогічні абсолютні значення напружень. Коли значення напруги зсуву перевищують значення напруги майже зруйнованої системи, вона характеризується найнижчими значеннями в'язкості. Реологічні властивості водних розчинів гуарової камеді важливі для розуміння процесів утворення структури, що відбуваються. Отримані результати можуть бути використані під час моделюванні стабілізаційних систем для виробництва нежирних майонезів і соусів.*

***Ключові слова:*** *стабілізація, гуарова камедь, галактоманан, реологічні властивості, в'язкість, структура.*