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Structure Formation in Food Systems Based on Agar-Agar and Melon Pulp

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Abstract. Actions devoted to search components of special application gets notable actuality at the present time due to unfavourable influence of environment. Confectionery and food productions based on structured pulps are especially valuable from this point. Natural biopolymers such as gelatin, starch, agar-agar are applied as structure formation materials at confectionery. However structured gels based on individual polymers possess with increased elastic-strengthening characteristics and so to the production technology of these gels must include processes for regulation its properties. In this work were defined peculiarities of structure formation of agar-agar-melon pulp system. It is stated that melon pulp in an individual state does not get structurized, however, its introduction into agar increases the strength of the system and decreases the critical concentration of structure formation of the agar-agar from 0.75 % to 0.25 %. Structure formation is realized by hydrogen bonds of COOH-groups of galacturonic acid of melon pulp and OH-groups of agar as well as hydrophobic interactions between non-polar parts of these substances.

Keywords: structure formation, agar-agar, melon pulp, H-bonds, hydrophobic interactions

1. Introduction

Unfavorable ecological situation as a result of anthropogenic activity of man requires the increase in the share of foodstuffs with minimum amount of synthetic ingredients which can exert a side effect on a living organism. Also, of special importance are investigations on formulations of foodstuffs able to remove radionuclides from the organism. Due to their unique biological and chemical properties pectines are the main components of many foodstuffs of dietetic and prophylactic purposes. They excrete heavy metal ions and radionuclides, improve gastrointestinal tract. Therefore, production of easily assimilable confectioneries from pectin containing raw materials distinguished by a high food value is quite actual. Such food systems are gelatinized foodstuffs: fruit jellies, jams, pastila [1], [2].

The main structure forming components of confectionery gels are biopolymers [3], [4]. The available in literature data on their structurization deal with gelatinization of separate polymers. As far as investigations on the technology of confectioneries are concerned, they do not pay due attention to the mechanisms of interaction of their ingredients. For this reason, the aim of this work is to definition of structure formation peculiarities of agar and melon pulp system.

2. Experimental

Natural polymer – agar was used as a jellifying polymer. To obtain melon pulp, the soft part of melons was separated from seeds and mixed in a mixer to a homogeneous mass.

The sugar and citric acid were used as other food ingredients.

To determine the degree of polymer structurization, Veiler-Rebinder's method was used which helps to measure the force of separation of goffered plate from the structured gelatine. The strength of the system was

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determined by equation P=F/2S, where F is the force used to separate of the plate from gel, N; S is the surface area of the plate, m^2.

Viscosity of agar mixtures with melon pulp and sugar was determined using Ubbelode's viscosimeter. For that, the melon pulp was passed through. Shott's filter and the liquid phase were used.

All structure formation experiments and viscometric studies were carried out at 298 K.

3. Results and Discussion

Fig. 1 presents the curves of structurization of agar in the presence and absence of melon pulp.Critical concentration of structure formation (CCS) obtained from the curve of structurization for agar made up 0.75 % (Fig. 1). Such a low value of CCS shows a tendency of agar to structure formation. For example, at 298 K this value mates up 1 % for gelatin and 10 % for methylcellulose [5]. The structure forming ability of agar can be explained by the diversity of functional groups in its macromolecules. Alongside with carbohydrates, it contains calcium and structure magnesium salts of sulphuric acid esters, hence, dissociation of $-OSO_3^-$ - group's takes place and agar shows properties inherent to polyelectrolytes [6].

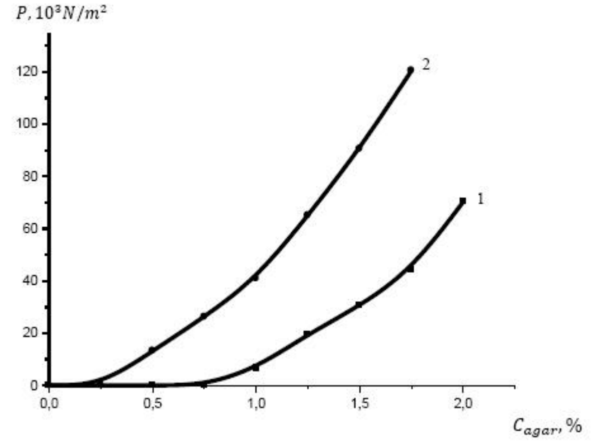

Fig. 1: The curves of structurization of agar (1) and the mixture agar- melon pulp (2)

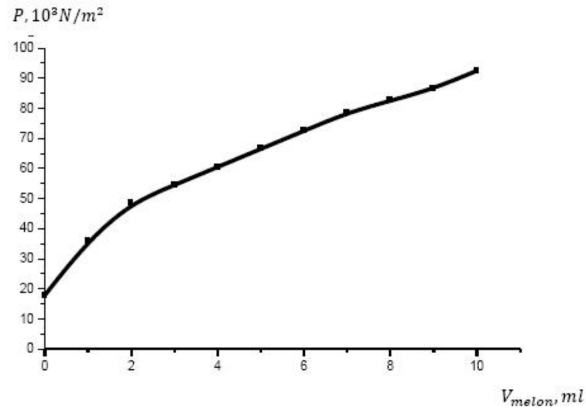

Fig. 2: The effect of melon pulp volume on structurization of agar$V_{agar} = 10\ ml;\ C_{agar} = 1{,}0\ \%$

Addition of melon pulp to agar increases the degree of structure formation. First, this can be observed by a sharp increase in the values of jellies strengths (Fig. 1, curve 2). For example, at concentration of the polymer 1.5 % the strength increases from 30 $\cdot 10^{-3}$N/m^2 to 90 $\cdot 10^{-3}$ N/m^2. Secondly, the increase in the strength leads to the decrease in CCS: this value makes up 0.75 % for agar and 0.25 % for agar-melon pulp system.

To substantiate such favorable effect of melon pulp on structure formation of agar, let us consider its composition. Melon contains 82.6 % of water, 16.5 % of carbohydrates, the rest are fats and proteins. Consequently, the main share in melon after water is made up by carbohydrates which provide a sweet taste of sugar: succharose glucose and fructose. Of these sugars, succharose makes up 60 – 70% and the cross-linking agents of cell shells are polysaccharides. They are present in melon in the form of pectines and hemicelluloses [7].

Besides, the data on the strength change of jellies agar-melon pulp (Fig. 2) depending on the content of melon pulp also show the structurizing effect of melon pulp.

Pectine is a polymer of galacturonic acid and some carboxylic groups in its composition are metoxilized, the degree of metoxilization reaches 60% [8]. In literature there occurs an opinion that pectine without such metoxilized group is not able to structure formation [9]. Thus, predominance of carbohydrates in both systems taking part in structure formation creates conditions for formation of hydrogen bonds and realization of hydrophobic interactions between them.

To determine the contribution of hydrogen bonds and hydrophobic interactions, structurization of agar and the agar-melon pulp system in the presence of carbamide (Fig. 3) was studied. This is related to the fact that molecules of such substances as alcohols and carbamide orienting hydrogen bonds to themselves are able to destruct the formed structures. In this case, not only hydrogen bonds but also hydrophobic interactions get destructed.

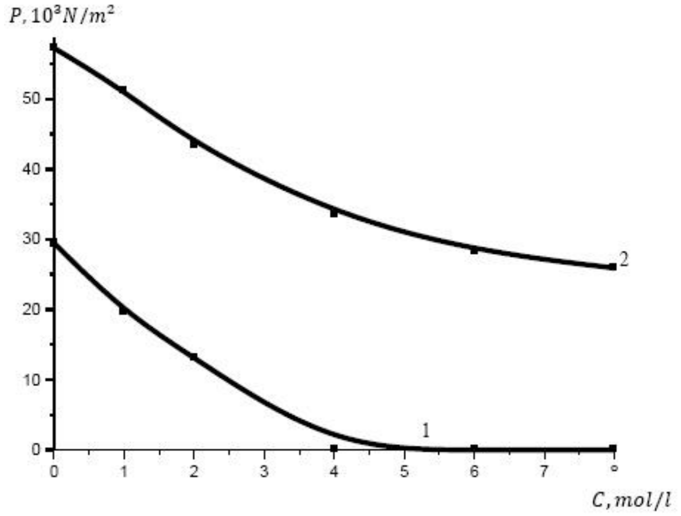

Fig. 3: The effect of carbamide concentration on structurization of agar (1) and the mixture agar – melon pulp (2)

Table 1: Chemical Content of Melon Pulp

Substances	Quantity, %
Water	82,6
Ash	0,4
Fats	0,1
Carbohydrates	16,48
Proteins	0,42
Energy value, Kcal/100g	68
Vitamins	mg, %
β – carotene	0,17
E	0,06
PP	0,23
C	14,5

As the results show, the structure of agar is destructed completely at carbamide concentration of 5 mol/l, while in the presence of melon pulp the value P decreases but is preserved in the field 30 $\cdot 10^{-3}$N/m^2 even at carbamide concentration of 8 mol/l. This indicates the determining role of hydrophobic interactions between non-polar parts of carbohydrates alongside with hydrogen bonds.

Food systems are quite complex by their chemical composition (Table 1). To regulate the flavoring properties, marketable state and to prolongate the storage term, food colors, aromatizing substances and preservatives are added to them. In the composition of confectioneries there must be sugar and citric acid due to their flavoring properties and preserving effect. In this regard, the effect of sugar and citric acid (CA) on structurization of the agar – melon pulp system was studied (Fig. 4 and 5).

It is interesting that the effect of sugar concentration on the strength (P) curve of agar itself passes through minimum, while for the agar-melon pulp system one can observe the increase in the strength with the increase in the content of sugar in the system (Fig. 4) The decrease in the strength of agar gelatin at low concentrations of sugar ($C \leq 0.05\%$) is explained by destruction of H-bonds in polymer solution. However, the increase in the content of sugar results in dehydration of the system and, consequently, the growth of gelatin strength.

To elucidate the mechanism of interaction of food jellies ingredients, viscosimetric investigations were carried out (Fig. 5). The minimum on the curve of viscosimetric titration of agar by melon pulp can be explained by compactization of macromolecules due to interaction of high molecular components of the system, i.e. formation of an interpolymer complex between macromolecules of agar and pectines of melon pulp. The increase in viscosity with the increase in the content of melon pulp is likely to take place due to saturation with COO^- - groups of the formed complexes agar-galacturonic acid, this leading to their mutual repulsion and, consequently, the increase in the sizes of macromolecules. The decrease in the reduced viscosity in the system agar-agar-sugar can be explained by formation of hydrogen bonds between dissociated groups of agar and sugar that prevents their participation in the processes of electrostatic repulsion.

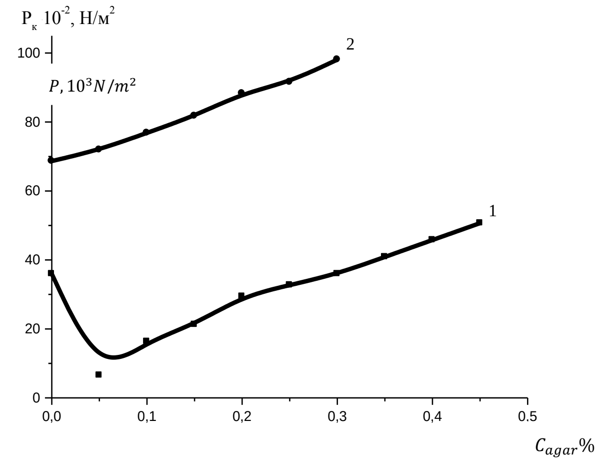

Fig. 4: The dependence of the strength of agar jellies (1) and the mixture agar-melon pulp (2) on sugar concentration.

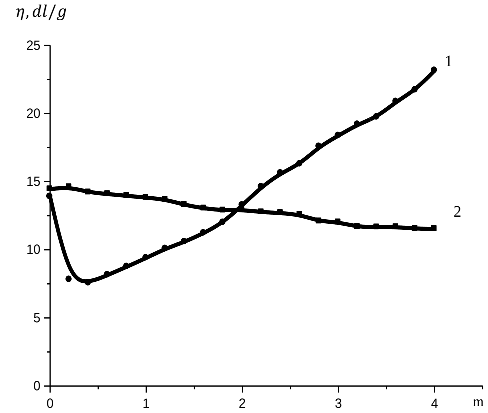

Fig. 5: The curves of viscosimetric titration of 0.005% agar solution with melon pulp (1) and sugar concentration (2) on m. m-s mass ratio melon pulp/agar (1) and sugar/agar (2).

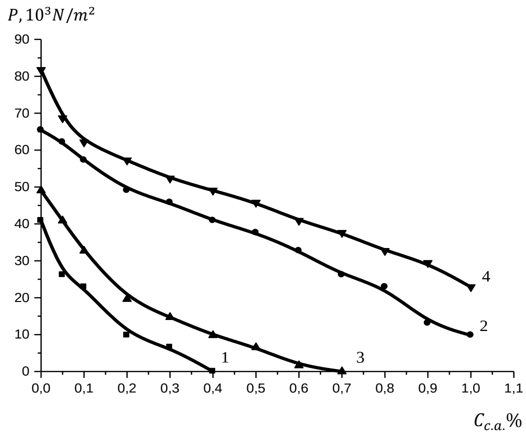

Fig. 6: The effect of citric acid on structurization of agar (1), mixtures agar-melon pulp (2), agar-sugar (3) and agar-melon pulp –sugar (4).

Introduction of citric acid into food systems on the basis of agar and melon pulp leads to the decrease in their strength (Fig. 6). This can be explained by concurrent interaction of citric acid with the food system components with formation of H-bonds.

A determining contribution of hydrogen bonds to structure formation of the studied systems is also indicated by the values of the melting point of jellies. For example, addition of melon and sugar to agar separately leads to the equal change of melting points and their simultaneous introduction into the polymer significantly increases the melting point of the jellies, this indicating the increase of H-bonds contribution in the structure formation process (Table 2). Thus, the effect of sugar on structure formation of agar is significant in the presence of melon pulp.

Table 2: The Melting Points of Jellies Based on Agar

The composition of jellies	Melting point, *K*	The composition of jellies	Melting point, *K*
Agar-water	348	Agar-melon-water	358
Agar-water-sugar	353	Agar-melon-water-sugar	363
Agar-water-sugar-citric acid	338	Agar-melon-water-sugar- citric acid	358
Agar-water- citric acid	318	Agar-melon-water- citric acid	333

The processes of formation of a new phase in polymer systems are related to the quality of solvent. The decrease in melting of jellies agar –melon pulp-sugar under the effect of citric acid can be explained by its hydrotropicity also.

Thus, we have obtained food jellies on the basis of agar and melon pulp. Structurization of the systems is realized on account of hydrogen bonds between carboxylic groups of galacturonic acid of pectines and OH-groups of agar.

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