Study of technological factors impact on the viscosity of "Wheat starch-Tween 20 (E432)" system

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Abstract

Introduction. The purpose of this article is to study the impact of technological factors (temperature, sugar, citric acid) on the model system "Wheat starch-Surfactant", which is the basic foundation for the realization of mousses technology using wheat starch.

Materials and methods. The viscosity of the model systems "Wheat starch-Tween 20 (E432)" with white sugar and citric acid under the temperature influence was measured on a rotary viscometer of VPN-0.2 type.

Results and discussion. The literature contains enough information about the progress of gelatinization process of different types of starches and the impact of various factors, including surfactants, acids, salts, sugar and others on it, however data about the impact of these substances on "Wheat starch-Tween 20 (E432)" system are absent.

Understanding changes in the properties of "Wheat starch-Tween 20 (E432)" system under the influence of various technological factors will allow to create the scientific base for the implementation of technology of new products with foamy structure.

The studies confirmed the feasibility of using Tween 20 (E432) with wheat starch as structure-maker of system, which will provide the necessary viscosity at the expense of dynamical phase transitions at heat treatment. The presence of Tween 20 (E432) in the system enhances the starch gelatinization temperature and decreases the viscosity values at the beginning of the process, providing conditions for foaming.

Adding of white sugar and citric acid inhibits the viscosity growth in the temperature range of 60–65 °C, the further temperature increase promotes the increase of indicators.

Thus, "Wheat starch-Tween 20 (E432)" model system rational parameters that will provide the optimal viscosity, which is necessary to obtain high indicators of the foaming capacity during whipping, are Tween 20 (E432) concentration – 0.25 %, wheat starch concentration – 6–12 %, white sugar concentration – 10.0 %, whipping temperature – 60–65 °C. These options will allow to obtain mousses using wheat starch and Tween 20 (E432) with new consumer characteristics by the realization of functional properties of wheat starch and surfactant.

Conclusions. The rational parameters of heat treatment of model systems using wheat starch and Tween 20 (E432) in order to provide the lowest viscosity indicators that will promote the maximal foaming capacity and will allow to realize the mousses technology were defined and substantiated.

Introduction

Modern food production conditions increasingly require from manufacturers to improve the technology of food production and to refine consumer characteristics and dictate trends of new technologies development to the scientists.

The monitoring of the food market shows that the most popular among consumers are sweet dishes, which are dispersed systems containing respectively at least two phases – dispersed phase and dispersion medium.

The most common representatives of this group are sweet dishes with gel- (jelly-) like and foamy (mousses, sambucas, creams, souffles) structures that are multicomponent mixed dispersed systems i.e. both foam and emulsion or emulsion and suspension with the possible priority of one of system types.

It is known that for foamy structure obtaining usually poultry eggs or gelatin is used, while starch in the composition of desserts serves as a thickener. The most often used are the starches whose properties are changed by various factors (pregelatinized, cold-swelling et al.), that promotes to more rapid progress of technological processes and formation of food systems with predetermined viscosity characteristics. In the scientific literature there is no information about the starches using in recipes of sweet dishes with foamy structure.

In view of analytical researches and innovative idea of the new products we have defined the innovative strategy of mousses technology development, which is to regulate the dynamic phase transitions of native wheat starch together with surfactant, as which Tween 20 (polyoxyethylene (20) sorbitan monolaurate, E432) was elected [1].

At the first stage of the technology implementation we obtained a model system "Wheat starch-Tween 20 (E432)", which was characterized by high levels of foaming ability (FA) at 60 °C, but thermodynamically unstable in time. In order to stabilize the foam system it is proposed its further heating up to 85±2 °C, that will result in gelatinization of the rest of starch achieving the effect of concentration stabilization of the foam by injection of additional heat and mechanical energy [2].

It is known [3] that the structure of disperse systems is determined by:

– properties of the dispersed phase particles;
– properties of dispersion medium;
– interaction between the particles of the dispersed phase and the dispersion medium;
– interaction of the dispersed phase particles with each other.

The properties of the dispersed phase and dispersion medium and their interaction together characterize inherent for food products structural-mechanical properties, one of which is viscosity.

Viscosity is the body's ability to resist relative displacement of its layers. For non-Newtonian (abnormally viscous) fluids, the viscosity is variable value that depends on shear stress and velocity gradient.

Published data indicate that many scientists devoted their researches to studying of behavior of different types of native starches, such as changes in viscosity depending on the processing temperature and the presence of other components in system such as surfactants, sugar, acid, salt and others.

It is known that the presence of chemical substances affects the nature of gelatinization. Some salts are capable to destruct the hydrogen bonds, what promotes the gelatinization start (Leanch, Lindqvist) [4, 5], while others inhibit it and act as salting-out agents (Ganz, Lindqvist) [5]. Sugar is known as a substance that is capable to slow down the gelatinization process by inhibiting of the starch granules swelling in water systems (D'Appolonia, Bean and Yamazaki, Savage and Osman, Wootton and Bamunuarachchi)

[5]; some lipids form complexes with amylose, thereby changing the gelatinization nature (Collison and Elton, Osman, Ito, Ghiasi) [5].

Other researchers note that adsorbing on the surface of the starch granules surfactants can reduce the viscosity and the swelling ability [6, 7]. Azizi and Rao [8] studied the effect of such surfactants as sodium stearoyl-2-laktylat (SSL, anionic surfactant, HLB=10–12), diacetyl tartaric acid esters of monoglycerides (DATEM, anionic surfactant, HLB=8–10), glycerol monostearate (GMS, nonionic surfactant, HLB=3–4), distilled glycerol monostearate (DGMS, nonionic surfactant, HLB=3–4) and noted that the injection of these surfactants increases the gelatinization temperature and decreases the peak viscosity, but its growth was noticed during cooling especially for SSL.

Lehrman [9, 10] indicates that the interaction between starch and surfactant depends on the surfactant adsorption on the surface of the starch granules. His further research showed that surfactants form insoluble compounds with amylose. Some surfactants form complexes with amylose and influence on the process of starch gelatinization. Krog [10], who noticed the ability of some emulsifiers to form complexes with amylose, found that distilled monoglycerides (DMG) have the best ability to form complexes among nonionic surfactants; sodium stearoyl laktylat (SSL) and calcium stearoyl laktylat were the best among ionic. These differences turned out to be associated with the length of hydrocarbon chains, the number of hydrocarbon chains in molecules and the structure of hydrophilic residues. Krog and Nybo-Jensen [9-11] showed that the ability of monoglycerides to form complexes with amylose depends on the physical form of surfactant.

It is known that the addition of surfactant reduces maximal viscosity with the increasing of initial and maximal gelatinization temperature. For sucrose esters [12] such behavior is explained by the formation of a combination of emulsifier-starch by the interaction of hydrophilic groups that form hydrogen bonds. Esters also can penetrate inside the amylose spiral structure and unite in supramolecular structures with hydrophobic bonds, reducing the hollow amylose structure. As a result the dissolution rate of starch increases and viscosity decreases. Thus results of many researches show that different in character surfactants differently interact and affect the starch during the heat treatment.

Sugar is one of the main components of desserts recipes, which affects the viscosity of starch suspensions during heat treatment [13, 14]. Fasihuddin and Williams studied the effect of sugar on sago starch and found that it increases the gelatinization temperature and the starch swelling increases to 25.0 % in the presence of sugar. Al-Malah, Azzam and Abu-Jdail determined a similar pattern for wheat starch at the presence of glucose to 6.0 %. Thus the addition of sugar to starch suspensions promotes the increase of temperature of viscosity growth start (initial gelatinization temperature), increasing the maximal system viscosity.

The basis for many sweet dishes is fruit raw material, which contains organic acids (citric, malic, lactic, etc.) in its composition. Also organic acids are specially added as an acidity regulator, antimicrobial, aromatic or preserving substances [15]. Despite the importance and prevalence of the interaction between organic acids and starch, information about them is limited. Most researches are devoted to the study of the process of starch hydrolysis under the influence of acids at high temperatures.

Summing up the above we can say that in the literature there is information about the impact of certain surfactants, acids, salts, sugars on the different kinds of native starches, but there is no data about the effect of these substances on "Wheat starch-surfactant (E432)" system. Since the scientific substantiation of mousses technology using Tween 20 (E432) as a foaming agent and wheat starch as structurant oversees the understanding of changes in functional and technological properties of starch during the technological process, the investigation of influence of different technological factors on the aforementioned model system will allow to create a scientific basis for new products technology implementation.

Materials and methods

The research materials were such model systems:
– Tween 20 (E432) and wheat starch aqueous solutions;
– Tween 20 (E432), wheat starch and white sugar aqueous solutions;
– Tween 20 (E432), wheat starch and citric acid aqueous solutions;
– Tween 20 (E432), wheat starch, white sugar and citric acid aqueous solutions, that were obtained by the combination of components with distilled water.

Determination of the effective viscosity was carried out on a rotary viscometer of VPN-0.2 type [16]. Electric structural scheme of viscometer is shown on Figure 1.

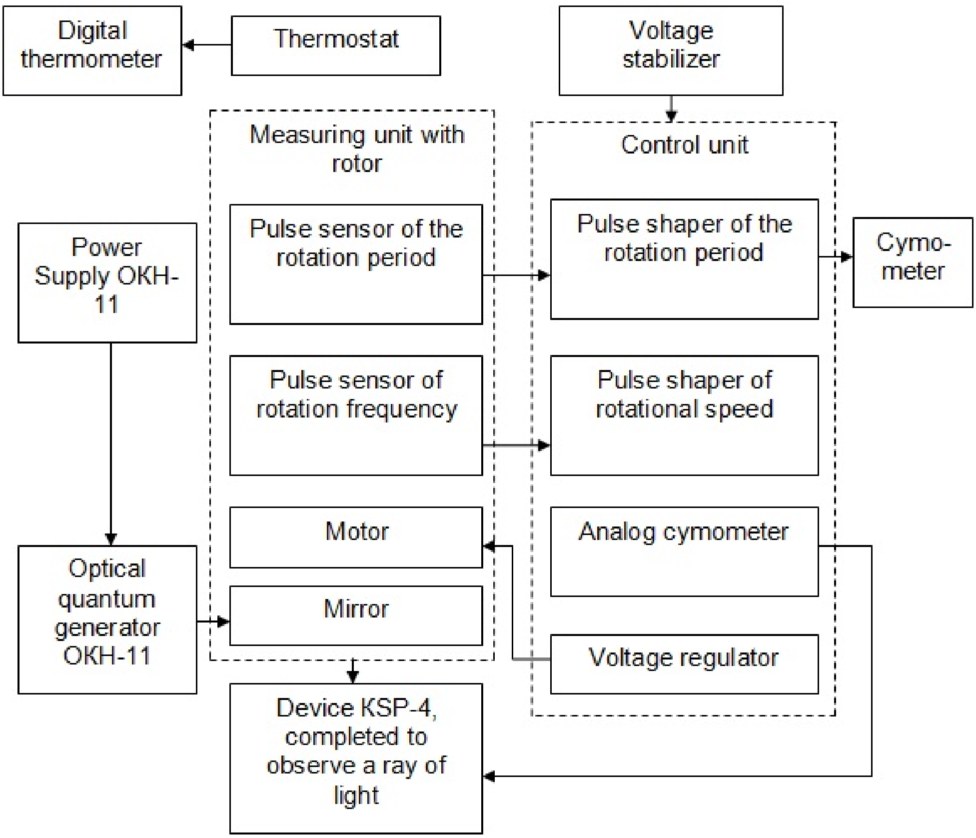

Figure 1. Electric structural scheme of viscometer VPN-0.2M

For the determination of the effective viscosity samples were prepared as follows: at the temperature 20 °C the components of the model system and distilled water were put together and heated with constant stirring in a water bath to 60 °C. Heated sample was transferred to the measuring unit of VPN-0.2, which was previously set in a thermostat at 60 °C, and left for (5–7)·60 seconds to restore the temperature then measurements were performed. After the reading of results the temperature in the thermostat was increased at 5 °C and after reaching the set temperature the device values were read again. Heating was carried out with stirring.

For measurements at VPN-0.2 the prepared sample was loaded into a measuring unit ($50 \cdot 10^{-6}$ m^3). Gradually increasing the voltage by a handle "Setting the voltage" rotation period was picked so that the viscosity values for samples were calculated at the same values of shear rate. For the fixed voltage value five values of the rotation period were read, excluding serious mistakes the average was found. For the obtained values of the rotation period voltage values in volts were noted and its average was found.

Dynamic or effective viscosity (η, Pa·s) was determined by the formula 1:

$$\eta = k \cdot U \cdot T \cdot A \tag{1}$$

where k – constant of measuring unit, Pa/V;
U – voltage, V;
T – rotation period, s;
A – measuring unit shape coefficient.

The shear rate ($\dot{\gamma}$, s^{-1}) was determined by the formula 2:

$$\dot{\gamma} = \frac{1}{T \cdot A} \tag{2}$$

To compare the viscosity of two or more samples the viscosity with the same shear rate in the field of minimal viscosity of the destroyed structure that was 320 s^{-1} was compared.

Results and discussion

Within the framework of innovative idea realization the aim of the study was to determine the influence of white sugar and citric acid as mousses recipe components on wheat starch in the presence of Tween 20 (E432) with heating (at temperatures above 60 °C). Wheat starch concentration in model systems was 8.0 %.

Firstly the impact of Tween 20 (E432) concentration at the viscosity of wheat starch suspension at different processing temperatures was determined (Figure 2). It is known from the literature sources that gelatinization temperature of wheat starch lays within the range 60 °C (initial)...80 °C (final), and the pasteurization temperature, which provides microbiological purity and stability is 90±2 °C, so exactly in this temperature range studies were carried out.

It can be seen from Figure 2 that the presence of chosen surfactant in the system reduces viscosity values of starch suspension in 2–2.7 times for a system containing Tween 20 (E432) at 0.3 % concentration and slows the beginning of viscosity growth at the temperature range 60–70 °C, i.e increases the wheat starch gelatinization temperature.

Since the viscosity of starch systems did not differ with adding Tween 20 (E432) at concentrations of 0.2 % and 0.3 % at the temperatures 60–70 °C, and at 90 °C the difference was only $0.14 \cdot 10^{-2}$ Pa·s, so for further studies 0.25% Tween 20 (E432) was elected as a working concentration.

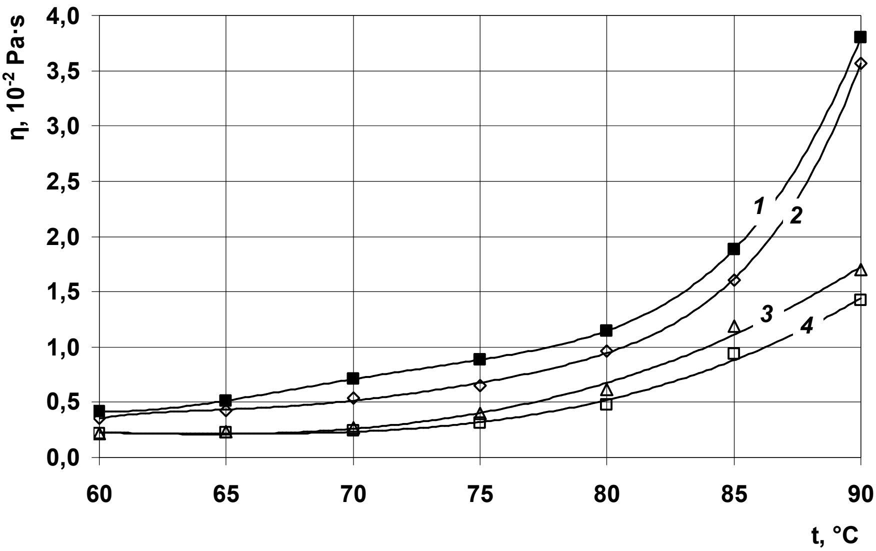

Figure 2. Changes of the effective viscosity of wheat starch suspensions depending on the treatment temperature at the concentration of Tween 20 (E432): *1*■ – 0; *2*◊ – 0.1; *3*Δ – 0.2; *4*□ – 0.3

In order to adapt the chosen model system to real technological conditions of production of sweet dishes, the influence of white sugar and citric acid on the viscosity values of "Wheat starch-Tween 20 (E432)" model system was studied.

Literature data indicate that sugar concentration in sweet dishes varies from 5.0 to 20.0 %, that provides good consumer characteristics. Known, that sugar has the structure-forming ability based on the property of sucrose solution to change system viscosity gradually at the temperature changes, while not altering the phase state.

With adding white sugar to "Wheat starch-Tween 20 (E432)" model system in the temperature range 65–70 °C viscosity increase was observed in 2–2.3 times in the presence of 5.0–10.0 % of sugar content and 3.4 times in the presence of 20.0% of sugar content (Figure 3). Viscosity values were $(0.23–0.3) \cdot 10^{-2}$ Pa·s at 65 °C and $(0.52–0.59) \cdot 10^{-2}$ Pa·s and $0.87 \cdot 10^{-2}$ Pa·s at 70 °C respectively. It should be noted that a further viscosity increase was observed at temperatures of 85...90 °C.

The obtained results (Figure 3) indicate that established by scientists patterns of the impact of sugar on the starch suspension at the heat treatment, as gelatinization temperature increase and maximal viscosity increase are also characteristic for the "Wheat starch-Tween 20 (E432)" system. For sugar content 20.0% the largest values of effective viscosity were observed ranging from 66 °C (at 70 °C the viscosity was $0.87 \cdot 10^{-2}$ Pa·s, and at 90 °C – $2.4 \cdot 10^{-2}$ Pa·s, whereas the system's viscosity without sugar was $0.26 \cdot 10^{-2}$ and $1.6 \cdot 10^{-2}$ Pa·s respectively). Obviously, at the gelatinization beginning sucrose delays the starch grains swelling in aqueous suspension by the increased dry matter content, what inhibits the beginning of viscosity growth at the temperature range 60...65 °C.

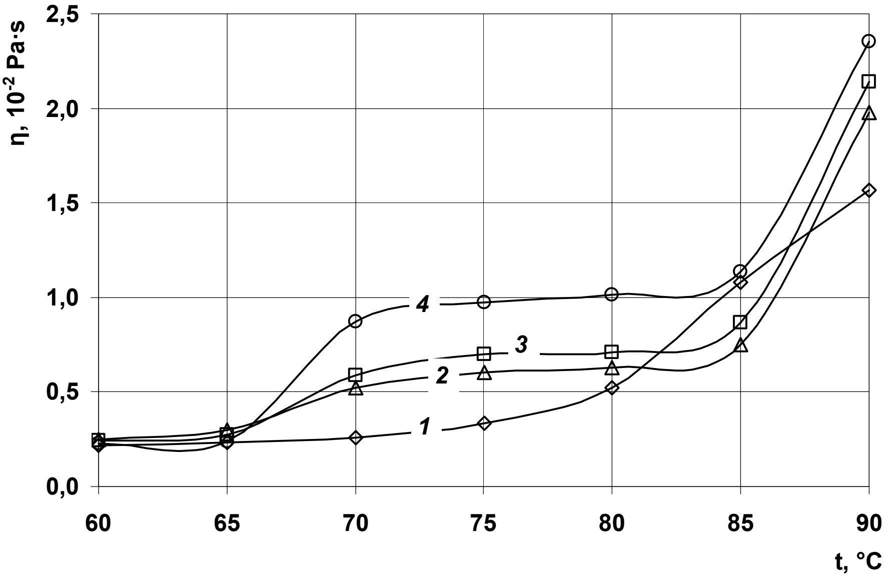

Figure 3. Changes of the effective viscosity of "Wheat starch – Tween 20 (E432)" model systems depending on the treatment temperature at the white sugar concentrations, %: ***1*◊ – 0; *2*Δ – 5.0; *3*□ – 10.0; *4*○ – 20.0**

Based on the viscosity values and organoleptic characteristics of new products the most appropriate concentration of white sugar in the system was chosen 10.0 %.

Thus in the desserts recipes fruit or vegetable raw material, which is characterized by certain pH, is used, we have modeled a food system in which the properties of the raw material were performed by citric acid.

The citric acid content was varied in the range of 0–1.0 %, which was elected in recalculation of pH of fruit raw material which is provided in the mousses recipe composition. The results of the citric acid impact on the viscosity of "Wheat starch-Tween 20 (E432)" model system are represented in Figure 4.

The results of determination of the effective viscosity of "Wheat starch-Tween 20 (E432)" model systems in the presence of citric acid showed a slight increase in values that was observed at the temperature 65±2 °C. So at 70 °C values have doubled, maintaining this trend to 85±2 °C. At the temperature 90 °C the largest viscosity characterizes model system with a 0.5 % concentration of acid, value of which amounted $5.1 \cdot 10^{-2}$ Pa·s, while the viscosity of a system without acid was $1.6 \cdot 10^{-2}$ Pa·s.

For the detection of joint influence of white sugar and citric acid on model systems the viscosity values at 10.0 % of white sugar and 0–1.0 % of citric acid content were determined (Figure 5).

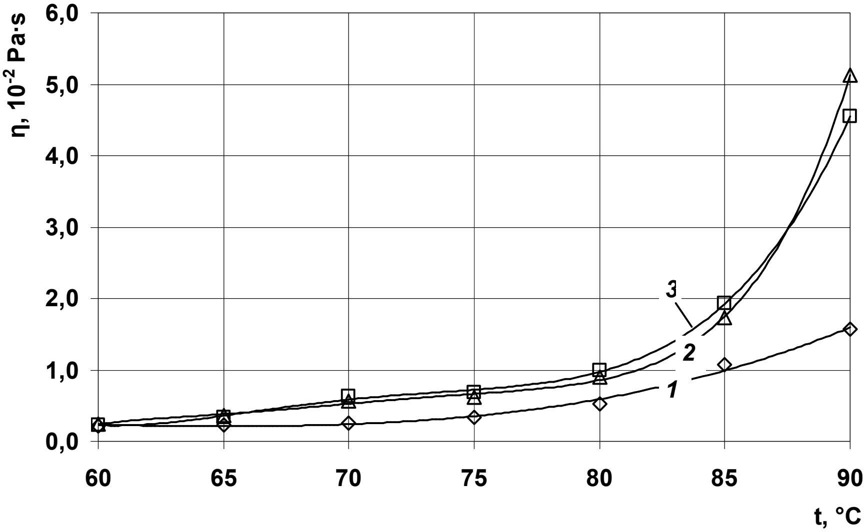

Figure 4. Changes of the effective viscosity of "Wheat starch – Tween 20 (E432)" model systems depending on the treatment temperature at the concentration of citric acid, %:
***1*◊ – 0; *2*Δ – 0.5; *3*□ – 1.0**

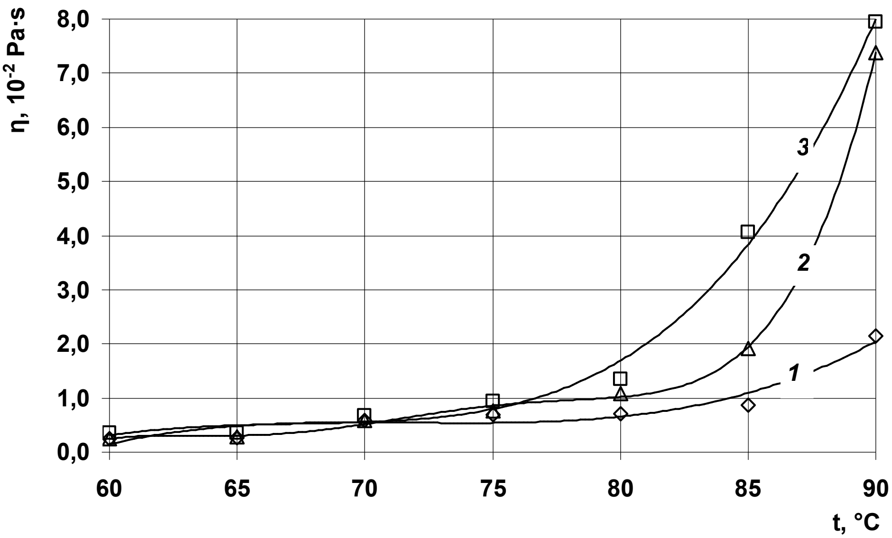

Figure 5. Changes of the effective viscosity of "Wheat starch – Tween 20 (E432) – white sugar" model systems depending on the treatment temperature at the concentration of citric acid, %:
***1*◊ – 0; *2*Δ – 0.5; *3*○ – 1.0**

The Figure 5 shows that the presence of citric acid in "Wheat starch-Tween 20 (E432)-white sugar" model system promotes the viscosity values increase beginning from 70 °C, and at 90 °C they are $7.4 \cdot 10^{-2}$ and $7.9 \cdot 10^{-2}$ Pa·s for systems containing 0.5 and 1.0 % of citric acid respectively, whereas the viscosity of systems without acid is $2.1 \cdot 10^{-2}$ Pa·s. The viscosity values of the investigated systems in the temperature range 60–70 °C almost does not depend on the content of citric acid and are at the level of values of "Wheat starch-Tween 20 (E432)" model system, that contains 10.0 % of sugar ($\approx 0.3 \cdot 10^{-2}$ Pa·s).

Conclusions

The obtained results testify that the presence of surfactant in "Wheat starch-Tween 20 (E432)" model system under the temperature impact promotes the decrease of the viscosity values of the system compared to starch suspension that doesn't contain E432.

We can assume that at the time of the addition of Tween 20 (E432) to the starch suspension its distribution on the surface of wheat starch grains (adsorption) takes place, which conduces to impeding of the water penetration to the starch grains and the decrease of viscosity. That is, the inhibition of swelling of starch grains in water systems occurs, that results in a shift of the initial gelatinization temperature toward larger values.

It should be noted that the presence of sugar and citric acid in a model system promotes the increase of the viscosity values that does not contradict scientific literature data. The important point is practically constant viscosity values in the temperature range 60–70 °C, that allows to implement an innovative idea.

References

1. Mriachenko N.V., Iurchenko S.L. (2016), Tekhnolohiia musiv promyslovoho vyrobnytstva, *Prohresyvni tekhnika ta tekhnolohii kharchovykh vyrobnytstv restorannoho hospodarstva i torhivli: zb. nauk. pr.,* 2(24), pp. 46–57.
2. Mriachenko N.V., Iurchenko S.L., Cheremska T.V. (2016), The substantiation of development of mousses technology using wheat starch, *Food Science and Technology,* 10(4), pp. 54-59, DOI 10.15673/fst.v10i4.255.
3. Koriachkina S.Ia., Prigarina O.M. (2011), *Nauchnye osnovy proizvodstva produktov pitaniia: uchebnoe posobie dlia vysshego professionalnogo obrazovaniia,* FGBOU VPO «Gosuniversitet-UNPK», Orel.
4. Day L., Fayet C., Homer S. (2013), Effect of NaCl on the thermal behaviour of wheat starch in excess and limited water, *Carbohydrate Polymers,* 94, pp. 31–37, available at: www.elsevier.com/locate/carbpol, http://dx.doi.org/10.1016/j.carbpol.2012.12.063.
5. Chungcharoen A., Lund D.B. (1987), Influence of solutes and water on rice starch gelatinization, *Cereal Chem.,* 64(4), pp. 240–243.
6. Ahmadi-Abharia S., Woortmana A.J.J., Hamerc R.J., Oudhuisb A.A.C.M., Loosa K. (2013), Influence of lysophosphatidylcholine on the gelation of diluted wheat starch suspensions, *Carbohydrate Polymers,* 93, pp. 224– 231, available at: www.elsevier.com/locate/carbpol, http://dx.doi.org/10.1016/j.carbpol.2012.05.020.
7. Ghiasi K., Hoseney R.C., Varriano-Marston E. (1982), Gelatinization of wheat starch. I. Excess-water systems, *Cereal Chem.,* 59(2), pp. 81–85.
8. Azizi M.H., Rao G.V. (2005), Effect of surfactant in pasting characteristics of various starches, *Food Hydrocolloids,* 19(4), pp. 739–743, available at: www.elsevier.com/locate/foodhyd doi:10.1016/j.foodhyd.2004.08.003.
9. Fredriksson H., Silverio J., Andemon R., Eliasson A.C., Aman P. (1998), The influence of amylose and amylopectin characteristics on gelatinization and

retrogradation properties of different starches, *Carbohydrate Polymers,* 35, pp. 119–134.
10. Shin M.-Sh. (1991), Influence of water and surfactants on wheat starch gelatinization and retrogradation, *Korean J. Food Sci. Technol.,* 23(1), pp. 116–121.
11. Krog N., Nybo-Jensen B. (1970), Interaction of monoglycerides in different physical states with amylose and their anti-firming effects in bread, *J. Food Technol.,* 5, pp. 77-87.
12. Zeng J., Gao H., Li G.L. (2013), Effect of Sucrose Esters on the Physicochemical Properties of Wheat Starch, *Tropical journal of pharmaceutical research,* 12(5), pp. 685-690, available at:
http://www.tjpr.org, http://dx.doi.org/10.4314/tjpr.v12i5.4
13. Abu-Jdayil B., Mohameed H.A., Eassa A. (2004), Rheology of wheat starch–milk–sugar systems: effect of starch concentration, sugar type and concentration, and milk fat content, *Journal of Food Engineering,* 64, pp. 207–212, available at:
www.elsevier.com/locate/jfoodeng, doi:10.1016/j.jfoodeng.2003.09.034.
14. Al-Malah K.I., Azzam M.O.J., Abu-Jdayil B. (2000), Effect of glucose concentration on the rheological properties of wheat-starch dispersions, *Food Hydrocolloids,* 14, pp. 491–496, available at:
www.elsevier.com/locate/foodhyd, PII: S0268-005X(00)00029-1.
15. Majzoobi M., Beparva P. (2014), Effects of acetic acid and lactic acid on physicochemical characteristics of native and cross-linked wheat starches, *Food Chemistry, 147,* pp. 312–317.
16. Horalchuk A.B., Pyvovarov P.P., Hrynchenko O.O., Pohozhykh M.I., Polevych V.V., Hurskyi P.V. (2006), *Reolohichni metody doslidzhennia syrovyny i kharchovykh produktiv ta avtomatyzatsiia rozrakhunkiv reolohichnykh kharakterystyk,* Kharkiv.