1. Introduction

An important condition for obtaining finished products with targets is predicting the behavior and effectiveness of the interaction of the individual components of the recipe in the process stream.

Food products (cultural products) as dispersed systems can be homogeneous or heterogeneous. Sauces, mashed soups, creams, fillers for confectionery products are multicomponent systems that undergo significant changes under the influence of technological factors. An important indicator of the quality of this culinary product is consistency – a complex multifactorial indicator, the formation of which depends on the colloidal state and dispersion degree [1, 2].

The difficulty of ensuring colloidal stability is determined both by the peculiarity of the recipe composition (acidic environment, the presence of slices of crushed fruit and berry raw materials, etc.), and by changes in the recipe mixture during processing, storage, use.

The study of factors in which the destruction of consistency occurs is very important for the justification and control of the technological process of production of culinary products. These include: mechanical or temperature effects, the amount of solids, the presence and effectiveness of the use of consistency regulators, pH, the effect of electrolytes.

The solution to the problem of ensuring the stability of disperse systems is facilitated by the introduction of thickeners that bind the liquid and increase the viscosity of the system. For example, starches, which can be native or modified [3, 4].

Today, modified starches are actively used, which, depending on the type of modification (chemical, physical, enzymatic), acquire new technological properties. But the use of chemical reagents, which belong to the group of food additives, limits the use in baby and diet food, the creation of organic products and detergents require the study of effective viscosity from the influence of technological factors.

The introduction of physical modification starches in the technology of culinary products requires the study of effective viscosity from the influence of technological factors.

The aim of research is determination of the rheological properties of gelatinized starch dispersions depending on technological factors (temperature, the effect of citric acid, sugar). This will allow to establish the influence of the parameters of the gelatinization process on the structural and mechanical parameters of gelatinized starch dispersions (GSD). This will make it possible to create products (sauces, creams, etc.) with new consumer properties, reduce the complexity and mechanization of the process.

2. Methods

Subjects of research:
– amylopectin corn starch (control) according to the regulatory documentation in force in Ukraine [6];
– waxy maize starch "Prima" 600, tapioca starch "Endura" 0100, tapioca starch "Indulge" 3920 of the Novation series [7].

The rheological characteristics of starch suspensions upon heating are determined on a Brabender amylograph [8, 9]. The initial temperature of the dispersion is 25 °C, the increase in heating temperature –1.5 °C per minute. The viscosity of the dispersions is expressed in arbitrary units of the amylograph (Brabender units) from 0 to 1000.

Energy changes in starch suspensions are determined by differential scanning calorimetry. DSC is performed for 1% starch suspensions in the temperature range of 20...100 °C, at an overpressure of 0.25 MPa and a scan speed of 2 K/min.

3. Results

The technological parameters of the gelatinization of starches that were used during the experiments are taken from previously scientifically based materials (Table 1) [10].
Thermodynamic research methods, for example, differential scanning calorimetry (DSC), are the most normative and accurate when determining specific heat [10]. This experiment confirms the amount of energy expended on the unpacking of starch grains. The results of calorimetric studies are shown in Fig. 1.

![Fig. 1. DSC curves for starch suspensions](image)

**4. Discussion and conclusions**

It should be noted that GSDs are visco-plastic thixotropic fluids for which the viscosity is a function of shear stress. The thixotropy of the studied systems is manifested in the presence of local values of the maximum and minimum viscosity, the ratio of the values of which determines the stability of the system (k = ηmin/ηmax) to external influences – temperature, acid, sugar.

Tapioca starches "Endura", "Indulge" and waxy maize starch "Prima" have a low gelatinization start temperature (58...62 °С). The maximum gelatinization temperature is 68...72 °С, the dispersion is characterized by viscosity values with a maximum stability coefficient of 1.0. This is probably due to the fact that the grains of the monodisperse fraction (≈83 %) [13], which in the grain distribution area swell and gelatinize equivalently.

For amylopectin corn starch, initial gelatinization occurs at a temperature of 72±2 °C, maximum gelatinization occurs at a temperature of 78±2 °C and lasts 3...4 minutes, after which it decreases. This is probably due to the fact that starches have a polydisperse fraction.

From the rheological studies of starches, it is determined that amylopectin corn starch does not meet the technological requirements for the production of food products with a colloidal structure. According to the influence of technological factors (citric acid, sugar), GSD based on amylopectin corn starch is not able to maintain stable viscosity indicators. This is explained by the fact that, according to their morphology and chemical composition, these starches have different grain rankings.

The studies provide an opportunity to study the features of the process of gelatinization, to identify patterns of GSD behavior in the presence of acid and sugar in the process of gelatinization.

Thermodynamic studies of starch suspensions, which describe the initial gelatinization processes, have shown that the unpacking of starch grains is characterized by endothermic peaks, which spend the energy of activation of moisture binding. As can be seen, the peak values of specific heat clearly correlate with the values of the initial gelatinization temperature. So for amylopectin corn starch they make up 72 °C, "Prima" waxy maize starch – 60 °C, for tapioca starches "Endura" and "Indulge" – 62 °C. The above research results are the main to justify the minimum temperature at which gelatinization of starches will be ensured during the production of food products of colloidal structure.

**References**

1. Li, H., Lei, N., Yan, S., Yang, J., Yu, T., Wen, Y. et al. (2019). The importance of amylopectin molecular size in determining the viscoelasticity of rice starch gels. Carbohydrate Polymers, 212, 112–118. doi: https://doi.org/10.1016/j.carbpol.2019.02.043
2. Sandhu, K. S., Sharma, L., Kaur, M. (2015). Effect of granule size on physicochemical, morphological, thermal and pasting properties of native and 2-octenyl-1-ylsuccinylated potato starch prepared by dry heating under different pH conditions. LWT - Food Science and Technology, 61 (1), 224–230. doi: https://doi.org/10.1016/j.lwt.2014.11.004
3. Aktaş, N., Gerçek ekal, K. E. (2019). Effect of Pregelatinization and Retrogradation on Some Physicochemical Changes of Wheat-Potato Starches. Journal of Agricultural Sciences, 25 (3), 281–289. doi: https://doi.org/10.15832/ankutbd.426252
4. Tao, J., Huang, J., Yu, L., Li, Z., Liu, H., Yuan, B., Zeng, D. (2018). A new methodology combining microscopy observation with Artificial Neural Networks for the study of starch gelatinization. Food Hydrocolloids, 74, 151–158. doi: https://doi.org/10.1016/j.foodhyd.2017.07.037
5. Postanova Rady (YeS) No. 834/2007 vid 28 chervnia 2007 roku stosovno orhanichnoho vyrobnytstva i markuvannia orhanichnykh produktiv, ta skasuennia Postanovy (YeES) No. 2092/91.
6. DSTU 3976-2000. Krokhmal kukurudzialnyi sukhyi. Tekhnichni umovy (2001). Kyiv: Derzhspozhyvstandart Ukrainy, 36.
7. Cornejo-Ramírez, Y. I., Martínez-Cruz, O., Del Toro-Sánchez, C. L., Wong-Corral, F. J., Borboa-Flores, J., Cinco-Moroyo-qui, F. J. (2018). The structural characteristics of starches and their functional properties. CyTA – Journal of Food, 16 (1), 1003–1017. doi: https://doi.org/10.1080/19476337.2018.1518343
8. Andreeva, S., Kolesnikova, M. (2014). Study of microstructure of physically modified starches to justify the use in sauce technology. Eastern-European Journal of Enterprise Technologies, 5 (11 (71)), 4–8. doi: https://doi.org/10.15587/1729-4061.2014.27571
9. Sikora, M., Kowalski, S., Tomasik, P., Sady, M. (2007). Rheological and sensory properties of dessert sauces thickened by starch–xanthan gum combinations. Journal of Food Engineering, 79 (4), 1144–1151. doi: https://doi.org/10.1016/j.jfoodeng.2006.04.003
10. Andreeva, S., Kolesnikova, M. (2017). The study of thermodynamic properties of physical modification starches in the production of sauces sweet. Food Science and Technology, 11 (2), 26–31. doi: https://doi.org/10.15673/fst.v11i2.510