STUDY OF THE EFFECTIVE VISCOSITY OF GELATINIIZED STARCH DISPERSIONS, BASED ON PHYSICALLY MODIFIED STARCHES, DEPENDING ON TECHNOLOGICAL FACTORS

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Abstract

The aim of the study is to investigate rheological properties of gelatinized starch dispersions, based on physically modified starches, depending on technological factors.

Realization of the research aim allows to get products (sauces, creams, fillers for confectionary products and so on), using physically modified starches, able to realize products with given structural-mechanical parameters of quality and safety; and also to provide the rational use of raw material resources, to decrease the labor capacity of the technological process of making culinary products.

There were analyzed modern development tendencies of technologies of physically modified starches and their use in food products technologies. Generalization of literary data became a base for using these starches in food products technologies, where the first turn attention is paid to the colloid stability of food systems.

Studies of the thermal stability of gelatinized starch dispersions determined that most stable in the cycle "heating-cooling-repeated heating" are gelatinized starch dispersions, based on physically modified starch "Prima", which effective viscosity doesn't essentially decrease after repeated heating. In gelatinized starch dispersions, based on physically modified starch «Endura» and «Indulge», repeated heating is also accompanied by the inessential viscosity decrease. Gelatinized starch dispersions, based on corn amylopectin starch, are not thermostable, and their effective viscosity essentially decreases at repeated heating. There are established regularities of the mechanical effect on structural-mechanical properties of gelatinized starch dispersions. It has been determined, that gelatinized starch dispersions, based on physically modified starches «Prima», «Endura» and «Indulge», demonstrate stable characteristics, as opposite to native starches at the mechanical effect.

The prospects of further studies in this direction are to investigate an influence of technological factors (change of pH medium, influence of enzymes, pectin substances, mineral salts) on structural-mechanical properties of gelatinized starch dispersions, based on physically modified starches.

Keywords: physically modified starches, effective viscosity, gelatinized starch dispersions.

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1. Introduction

An important condition for getting ready products with target parameters is to prognosticate a behavior and effectiveness of interaction between separate components of a recipe mixture in the technological flow.

Food products (culinary products) as disperse systems can be homogenous or heterogenic. Sauces, soups-purees, creams, fillers for confectionary products - are multi-component systems, subjected to essential changes under the effect of technological factors. An important quality parameter of these culinary products is consistence – complicated multi-factor parameter, which formation depends on a colloid condition, dispersion degree and so on [1, 2].

Understanding of factors, at which a consistence is destructed, is very important for reasoning and managing a technology of culinary products: mechanical or temperature effect; amount of dry substances, presence and effectiveness of using consistence regulators, pH value, effect of electrolytes.

Introduction of thickeners, binding a liquid and increasing the system viscosity favors solving a problem of providing stability of dispersion systems. One of them is starches that can be native or modified [3].

Modified starches that gain new technological properties depending on modification type (chemical, physical, enzymatic) are actively used today. But the use of chemical reagents that partially remain in the composition, affiliation to the group of food supplements with E index and are quantitatively regulated, limits the use in child and dietary nutrition, creation of organic products and determines the expedience of search and scientific substantiation of alternative starch types.

According to scientific studies [4–7], it may be stated, that both starch dispersion and structure and density of seeds package determine its behavior in the technological flow. It must be noted, that the existence of gelatinized starch dispersions at balance under condition of using starch seeds with different dispersions is essential because of the probability of maximums of free energy. The aforesaid determines the expedience of using starch with the homogenous distribution of particles by sizes, and in the aspect of providing stability of systems – starch seeds must be distinctly dispersed [8].

Due to innovations in the field of starch and starch products making, their new types with optimized characteristics are created together with classic types of native starches.

Group of companies «Ingredion» [9] produces a series of innovative starches «Novation» without «E» index, characterized with the high technological resistance and maximal stability. In the wide technological spectrum of products of different destinations (sauces, soups, fruit fillers, milk products) under conditions of intensive mechanical and thermal effects, «Novation» starches are declared as ingredients, able to form and to provide a certain structure. These starch types correspond to statement 834/2007 of the EU, so may be marked as “organization” ones [10].

Introduction of physically modified starches in technologies needs studying the effective viscosity at effects of technological factors.

The aim of the study is to investigate rheological properties of gelatinized starch dispersions, based on physically modified starches, depending on technological factors (temperature regimes (cooling, repeated heating, mechanical effect). It allows to establish an influence of gelatinization process parameters on structural-mechanical parameters of gelatinized starch dispersions (GSD). It gives a possibility to create products (sauces, creams and so on) with new consumption properties, to decrease the labor capacity and mechanization of the technological process.

It is necessary to solve the following problems, according to the set aim:

– to reveal a dependence of the effective viscosity of GSD, based on physically modified starches, depending on the cycle “cooling-heating”;

– to study a dependence of the effective viscosity of GSD, based on physically modified starches, depending on the mechanical effect.

2. Materials and Methods

Research objects were:

– corn amylopectin starch (control), according to normative documents, actual in Ukraine [11];

– starch of waxy corn «Prima» 600, tapioca starch «Endura» 0100, tapioca starch «Indulge» 3920 series «Novation» [7].

The GSD effective viscosity was determined on the rotation viscosimeter, type VPN – 0.2 [12].

The dynamic or effective viscosity was determined by formula:

$$\eta = k \cdot U \cdot T \cdot A, \quad (1)$$

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

The shift speed γ was determined by formula:

$$\gamma = \frac{1}{T \cdot A}, \ \%. \quad (2)$$

The shift voltage τ was determined by formula:

$$\gamma = k \cdot U. \quad (3)$$

For comparing viscosities of two or more objects, there was compared the viscosity with the equal shift speed, chosen in the field of maximal viscosity of the maximally non-destructed structure or the minimal viscosity of the destructed structure.

The statistical processing of the research results, graphs construction were realized by the software STATISTICA 13.3 (in the equipment Process Optimization) and MS Office Excel 2010.

3. Experimental procedures

Gelatinized starch dispersion (GSD) was obtained by heating starch suspension at temperature 60…75 °C. Starch suspension was obtained by suspending dry sieved starch with drinking water at temperature 20±2 °C.

The technological parameters of starches gelatinization, used at the experiments, were taken from earlier scientifically substantiated materials (**Table 1**) [13].

Table 1

Technological parameters of starches gelatinization

Starch name	Temperature of gelatinization, °C		GSD, Brabender un.		Relative stability coefficient
	initial	final	η_{max}	η_{min}	$\frac{\eta min}{\eta max}$
Corn amylopectin (control)	72±2	78±2	700±2	110±2	0,15
Of waxy corn	60±1	69±1	1000±2	1000±2	1,0
Tapioca «Endura»	58±2	68±1	920±2	920±2	1,0
Tapioca «Indulge»	62±2	72±2	980±2	980±2	1,0

For determining structural-mechanical properties of GSD at the cycle "heating-cooling-repeated heating", there was measured the GSD viscosity of starch content 7.0 % at temperature 70±2 °C, after cooling to temperature 1...6 °C and repeated heating to temperature 70±2 °C. The GSD heating temperature up to 70 °C is grounded by the fact that culinary products are served at temperature 65…70 °C that is why it is expedient to use temperature 70 °C as a confirmation of the starches stability at this temperature.

The effective viscosity of GSD under the mechanical effect was determined at different temperatures (70±1 °C, 4±2 °C) and rotation speed 1500±5 s^{-1}, during 5·60 s, shift speed 50 s^{-1}. The experimental parameters prove technological parameters of obtaining cream-like systems by shaking.

4. Results

4. 1. The study of a dependence of the effective viscosity of GSD, based on physically modified starches depending on the cycle "cooling-heating"

Real food systems (semi-products, ready products) are subjected to effects of many factors that can essentially change organoleptic, rheological, physical-chemical and other pa-

rameters. Taking into account the production technology of different types of products (sauces, creams, fillers), changes in starch systems in the cycle "heating-cooling-repeated heating" must be determined. It is known, that cooling of starch pastes is accompanied by appearing hydrogen bonds between chains of molecules, at that there is a tendency to gel creation at the expanse of appearing aggregates and partial crystallization. It may be accompanied by a changing consistence of ready products (thickening, texture deformation, moisture separation) that is unpermitted defect. **Fig. 1** presents the dependencies of the GSD effective viscosity on temperature.

The studies of the GSD thermal stability determined that most stable in the cycle "heating-cooling-repeated heating" is GSD, based on starch «Prima» (2), which viscosity decreases unessentially after repeated heating. For GSD, based on starch «Endura» (3) and «Indulge» (4), repeated heating is also accompanied by the unessential viscosity decrease – from 2.0±0.04 Pa·s to 1.9±0.04 Pa·s and from 1.8±0.03 Pa·s to 1.7±0.03 Pa·s, respectively. GSD, based on amylopectin corn starch, is not thermostable, and their effective viscosity at repeated heating essentially decreases from 2.1±0.04 Pa·s to 1.0 ±0.03 Pa·s.

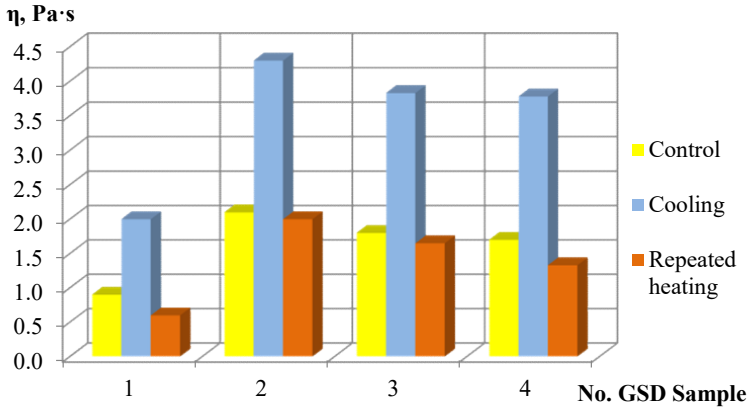

Fig. 1. Dependence of the GSD effective viscosity on temperature, based on starches (C_{starch}=7,0 %): 1 – corn amylopectin (control); 2 – of waxy corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca Indulge» (at ɣ=50 s^{-1})

4. 2. The study of a dependence of the effective viscosity of GSD, based on physically modified starches depending on mechanical effect

The influence of a mechanical action may be accompanied by deformation, stratification, foam formation and other changes. But the most essential mismatch is a change of viscosity, connected with starch mechanical destruction. GSD at the mechanical effect have a series of peculiarities, connected with their grainy structure, fraction composition and expressed viscosity anomaly (**Table 1**).

At the mechanical effect on GSD a degree of their dispersion increases at the expanse of mechanical splitting of swollen starch seeds, accompanied by the increased content of the water-soluble fraction [14–16].

But a starch type and GSD temperature essentially influence a mechanolysis degree. General tendencies for GSD at temperature 70±1 °C are presented as following: the least stability to destructing effects is revealed for GSD, based on corn amylopectin starch (stability coefficient 0.38). The abrupt viscosity decrease is connected with changing the initial structure of starch seeds, namely with destruction of the physical fluctuation net of starch dispersion.

Higher stability coefficients are inherent to GSD, based on starches «Prima», «Endura», «Indulge» (0.93; 0.81; 0.89 respectively), that testifies to their promising use in technologies of sauces, creams, confectionary fillers under conditions of the mechanical effect.

Table 2

Research data of the GSD effective viscosity depending on mechanical effect

Name of GSD, based on starches:	Effective viscosity value (Pa·s) of GSD at temperature, °C					
	70±1			4±2		
	Without mechanical effect (control)	At mechanical effect	Stability coefficient	Without mechanical effect (control)	At mechanical effect	Stability coefficient
Corn amylopectin (control)	1.20±0.02	0.50±0.01	0.38	2.10±0.03	1.0+0.02	0.48
Of waxy corn «Prima»	2.30±0.06	2.10±0.06	0.93	3.8±0.1	2.7+0.06	0.71
Tapioca «Endura»	1.90±0.05	1.60±0.04	0.81	3.7±0.1	2.5+0.05	0.67
Tapioca «Indulge»	1.70±0.05	1.60±0.04	0.89	3.7±0.1	2.0+0.06	0.56

After cooling and keeping the system at rest, there forms a physical net at the expanse of clutching between particles. It has been studied, that mechanical destruction of cooled GSD revealed analogous tendencies, but with the lower stability coefficient. The viscosity values decrease of GSD, based on corn amylopectin starch, tapioca «Endura», is almost twice. GSD, based on starches «Prima», «Indulge», are more stable to destructing effects (stability coefficient 0.71 and 0.56 respectively).

The analysis of the research results of the GSD effective viscosity allows to state that under the effect of mechanical actions, the viscosity decrease with stratification of GSD, based on corn amylopectin starch, takes place.

Certain differences were observed also in the outlook of dispersions, especially for GSD at temperature 4±2 °C: GSD, based on amylopectin corn starch, have the more liquid consistence, accompanied by dispersion fluidity.

5. Conclusions

It has been experimentally proved, that most stable in the cycle "heating-cooling-repeated heating" are GSD, based on physically modified starch "Prima", "Endura" which effective viscosity doesn't essentially decrease after repeated heating.

Thus, the modeling of conditions of the mechanical effect on GSD demonstrated that most stable are systems, based on starches of waxy corn «Prima» and tapioca «Endura».

Based on studying properties of starches of different trademarks, there has been established the expedience of using starches of physical modification «Prima», «Endura» at the expanse of their stable properties in the technological process. It may be also noted, that the main advantage of physically modified starches is their universal use in different food systems. For example, sauces, based on fruit-berry raw materials, soups-puree, decorative semi-products for confectionary products (creams, glazes, syrups and so on). But the use of these starches in food systems with a dispersed structure – emulsion has not been studied experimentally yet, that may limit their use in milk sauces, butter, protein creams and so on.

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