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The sweet sauces technology with physical modification starches use is considered in the monograph. The use of physical modification starches (PMS) from wax corn «Prima», tapioca «Endura», fruit and berry raw material (puree, concentrated juices) and flavoring components in the sweet sauces technology is substantiated. The effective viscosity dependences of gelatinized starch dispersions (GSD) and model systems (MS) on the base of experimental starches and fruit and berry raw material on technological factors effect (pH, reheating, mechanical action, «freezing – thawing» cycle, storage duration, etc.) were established. The rational content of the main recipe components and technological parameters of sweet sauces production are substantiated. Recommendations for sweet sauces with physical modification starches use for culinary products are developed.

The monograph can be useful for researchers, postgraduates, students who study in the specialty «Food Technology», as well as practitioners of the food and restaurant business industries.

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CONTENTS

PREFACE

Monitoring of the consumer market in Ukraine and in the world shows existence of the clear trend towards increasing of the demand for ready-to-use products. This tendency is determinative in HoReCa system, B2B, B2C business processes, at trade enterprises and identifies a wide range of problematic issues concerning the improvement of quality, efficiency of production technological processes, expansion of the range and improvement of consumption properties of products, provision, variation of storage periods.

Most of the sauces technologies innovations are implemented in mayonnaise and tomato sauces, and the development of the sweet sauces technology for today is aimed mainly at improving their nutritional value. However, in modern conditions the requirements for the assortment, production manufacturability, consumption properties of sauces, which must have stable indices under the destructive factors influence, change.

Functional and technological ingredients (FTI) become widespread in the world practice of sauces production, among which the starches variability is paramount. However, native starches have a number of limitations in use, which are low thermal and acid stability, tendency to syneresis, short shelf life, etc.

Technology scientific substantiation involves not only «ready» recommendations use, but also regularities understanding of starches functional and technological properties changes during the cycle «production – use in the products composition – storage» implementation.

With taking into account all abovementioned the substantiation of physical modification starches (PMS) use in the sweet sauces technology is significant scientific and practical task of industry importance; its solution will allow creating scientific base for the new products technology.

PART 1
MODERN TENDENCIES OF SWEET SAUCES PRODUCTION

1.1. Technological aspects of production and consumption of sweet sauces in modern conditions

During analyzing the Ukrainian market [1], it is possible to identify a number of tasks which are related to the production and sale of culinary products, namely the improvement of consumer properties (reducing the mass fraction of food additives), providing product safety; variation of storage periods, expansion of the range. But one of the topical problems is the necessity of providing the products' technological properties in the process of production, storage, sale and consumption.

Sauce is additional component of dish which is used for the preparation of semi-finished products, finished products during serving for more pronounced taste and aroma, juiciness of dishes and products obtaining [2–5]. It is possible to control nutritional and energy value of the dish through combination of the sauce and the main course.

Sweet sauces, which are traditionally made in restaurant business enterprises (RBE), are not presented in quite a wide range. The classification of sauces is based on the following features:

– type of basic raw material (fruit and berry, milk, etc.);

– serving temperature (hot, cold);

– the presence or absence of thickeners (it significantly affects on the technological process of production, preparation for consumption and consumption);

– shelf life (short-term, long-term).

Sweet sauces which are sold on the HoReCa network are represented by general-purpose sauces (toppings, desserts, stuffings) and specialized sauces (for example, for baby food) [6–8].

In the modern Ukrainian market, the sale of sweet sauces is provided through the network «producer – retail network – RBE – individual consumer». Such chain determines a number of technological requirements for the production and storage of sauces, first of all, the stability of organoleptic, physical and chemical, structural and mechanical parameters.

It should be noted that in recent years the «creative kitchen» is widely distributed; it is characterized by the combination of sauces with hot and cold dishes on the base of meat, fish, poultry, game [9; 10].

The rapid development of RBE, the formation of new culture of product consumption, contribute to the fact that sweet sauces went beyond the traditional technologies of RBE own production [11–14]:

– technologies of designated purpose sauces (dietary sauces with sugar substitutes, with additional introduction of vitamins and minerals) are developing;

– molecular kitchen technologies (sauces-foams, capsules, etc.) become more popular;

– express cooking techniques are used (for example «La minute» deglazing);
– specialized equipment is used (combined thermomixings, espumizer, etc.).

Both classic and modern approaches to the technology of sauces involve their gradation according to the consistency: liquid (dressings), medium thickness (sauces-toppings), thick (sauces-toppings, sauces-dip).

Analysis of the modern assortment of RBE products indicates the need to create sweet sauces of different consistency. So, liquid consistency sauces (dressings) are used as salad dressings. Medium-consistency sauces (toppings, dessert sauces) can be used for dishes or drinks decoration during preparation for sale. It is advisable to use thick sauces (fillings, dips) for stuffing culinary dishes and confectioneries, as well as for combined consumption with snack products.

The technological aspects of sweet sauces cooking are related to the creation of highly dispersed, time-stable systems. Destabilizing factors in the technology of sweet sauces include following:

– pH: use of fruit and berry raw material at pH of 5,5;
– time: duration of heat treatment in the production process, short-term or long-term storage (not less than 90 days at 1...6ºC temperature);
– mechanical impact of different intensity (from 1000 to 1500 s^{-1});
– temperature: heat treatment in the production process, reheating in the culinary products composition, confectioneries at temperature above 100º C; freezing at temperatures – 18ºC, defrosting).

Promising stabilizing agents today are functional and technological ingredients (FTI) of polysaccharide nature – modified starches, pectins, gums and other hydrocolloids. But the choice of FTI should not only be based on their effect on the destabilizing factors in the technological flow.

Important consumer characteristic of sauces, regardless of the recipe composition and production technological process characteristics, is the complex of organoleptic indices, according to which, above all, potential consumers assess the product.

Ranking of organoleptic indices by weight coefficients shows that consistency is a priority in addition to appearance. As it was noted earlier, it is relevant for sweet sauces to be classified into three groups, and the peculiarities of the sauces consistency can be presented as follows:

– dressings are homogeneous and liquid, spread rapidly on a horizontal surface;
– toppings are homogeneous or heterogeneous (with filler particles, etc.) and with «long» texture;
– fillings, dip are homogeneous or heterogeneous (with filler particles, etc.) and with «short» texture.

The limited production of sweet sauces is characteristic not of the RBE but also of the food industry enterprises. We developed the model of sweet sauces recipe composition on the base of fruit and berry raw material with use the recipe composition diagnostics of classic and modern assortment of own and industrial production sauces [15–19] (fig. 1.1.).

As we can see, the recipe composition of sauces of own and industrial production consists of the following groups:

– the basic fruit and berry raw material, which may be fresh or preserved (processed);

– structure-forming agents of polysaccharide nature;

– additional raw material which forms the assortment;

– components which form and regulate the structure.

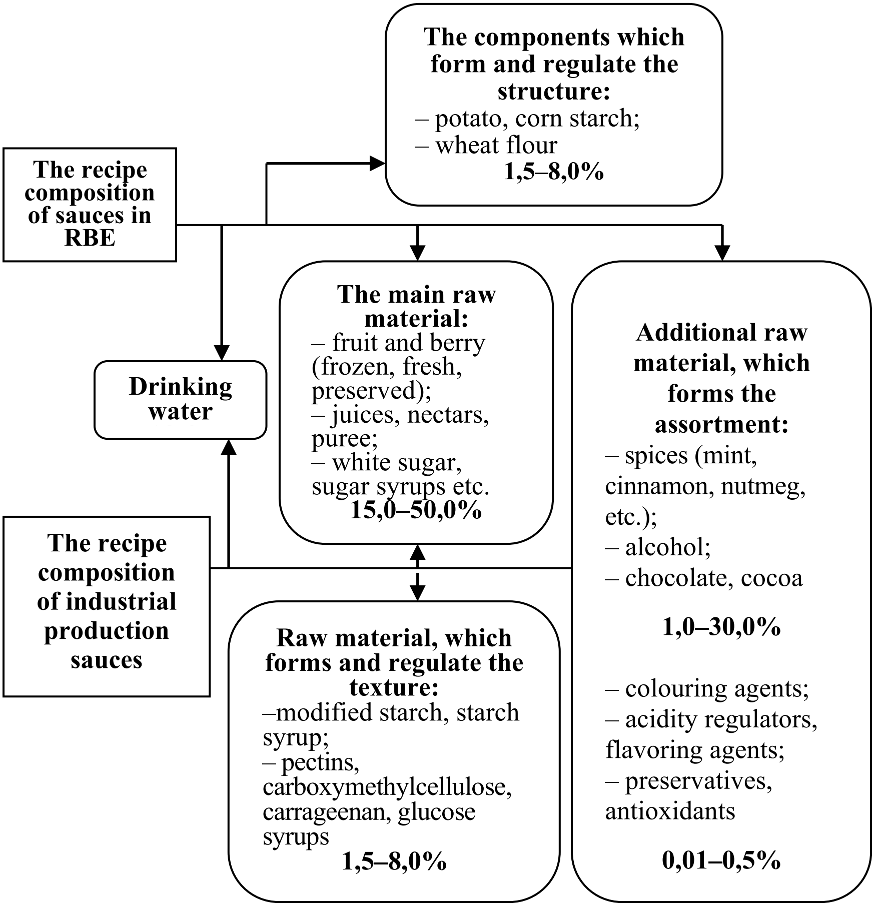


Figure 1.1. Model of the recipe composition of sweet sauces on the base of fruit and berry raw material which are produced in the conditions of RBE and industrial production

Traditionally, industrial sweet sauces include substances which provide textural stability: pectin, agar, gums, modified starches, and glucose syrups [20–25].

The substantiation of the thickener agents choice is based on their organoleptic characteristics, physical and chemical properties, features of interaction with other components, cost, usability.

Analytical review of information sources according to the problem [19; 26–32] shows that a number of studies were carried out to date for stabilization of the food systems by pectin, gum, carrageenan, sodium alginate and etc. In this scientific direction, significant contributions are made by such domestic and foreign scientists as P.P. Pyvovarov, O.O. Hrynchenko, L.P. Maliuk, M.F. Kravchenko, M.I. Peresichnyi, L.V. Donchenko, A.Yu. Kolesnov, A.Yu. Krupoderov, J.Y. Thebaudin, A.C. Lefebvre, S. Mali and others; the theoretical and applied aspects of the systems’ colloidal stability providing by using polysaccharide nature additives: pectins, alginic acids salts, carrageenans, gums, starches were considered in their scientific works; the possibility of obtaining a wide range of products with stable properties was proved.

Different types of fruit and berry raw material processing (mechanical – grinding, homogenization; thermal – cooking, sterilization and reheating) and pH medium changing affect the appearance of sauces, worsen their consumer properties. The use of colouring agents allows refreshing and intensifying the natural color of processed fruit and berry raw material, as well as creating a wide range of sweet sauces [16; 33; 34].

Formation of the necessary taste and aromatic characteristics of industrial production sweet sauces is facilitated by the use of flavors, sweeteners, acidifiers and flavor enhancers, which reduces their nutritional value and «attractiveness» for potential consumers.

The possibility and speed of the hydrolytic and oxidation processes, the development of unwanted microbial flora of sweet sauces are influenced by the composition and condition of the food system, humidity, pH medium, enzymes activity, features of the processing technology of fruit and berry raw material and production, storage and transportation conditions. Preservatives and antioxidants, which slow down microbiological and oxidative spoilage are used for sauces quality and safety providing [35; 37].

The modern assortment of sauces has a number of specific requirements which must be taken into account during recipe composition and production technological process substantiation, namely:

– a wide range of viscosity variations;

– uniform distribution of fruit and berry particles by volume (possibility of being suspended);

– resistance to freezing and preservation of consumer properties, the absence of thawing or «snowiness»;

– maintaining the consistency and product’s taste without changing the production process and storage (drying, delamination, etc.).

Recipe composition significantly influences the technological process of finished products production. There are a number of transformations both with the individual substances and with the recipe mixture as a whole during individual operations. Therefore, process understanding and control points identifying are important for further research. Raw material and semi-finished products are subjected to different types of processing (mechanical, physical, thermal), which cause certain biochemical transformations and affect the consumer properties of products during the technological process of sweet sauces production.

The main reactions which occurs during the fruit and berry raw material processing [33; 38; 39] and cause change of its consumer properties are:

– enzymatic and non-enzymatic oxidation of polyphenolic substances, in particular bioflavonoids;

– polymerization of oxidation products of polyphenolic substances, their reaction with metals, amino acids, etc.;

– vitamins' oxidation, first of all ascorbic acid oxidation;

– sugars' caramelization;

– some organic acids decomposition.

It is necessary to limit the oxygen access to the recipe composition during the process for quality of fruit and berry sauces providing. Oxidation occurs according to the radical and chain mechanism with quadratic chain termination, oxygen always catalyzes the anthocyanins' destruction, less it affects on flavonols.

With taking into account the negative effect of bioflavonoids' oxidative transformations on the products' quality, it is necessary to try to preserve them as much as possible during the technological process. Scientists [16; 40] propose a number of techniques for this purpose:

– use of fruit and berry raw material at the optimum ripeness stage, it helps to achieve the rational ratio of different forms of flavonoids which have reduced ability to oxidative transformations;

– choice of certain types and varieties of fruits with high content of anthocyanins, flavonols and low content of catechins.

The technological process of the sweet sauces production is presented in the form of model (fig. 1.2.), which defines the basic parameters of technological process management and control.

The following should be considered during substantiation the technological process of sweet sauces production:

– the sauce's purpose and the specifics of its use;

– the potential possibility of the fruit and berry base with the thickener interaction for obtaining the equilibrium thermodynamic system which does not change over time;

– parameters of separate technological operations (freezing, pasteurization, etc.), stability of sauce properties under certain conditions;

– compliance of the finished product storage modes in the chain «producer-consumer»;

– production economic expedience.

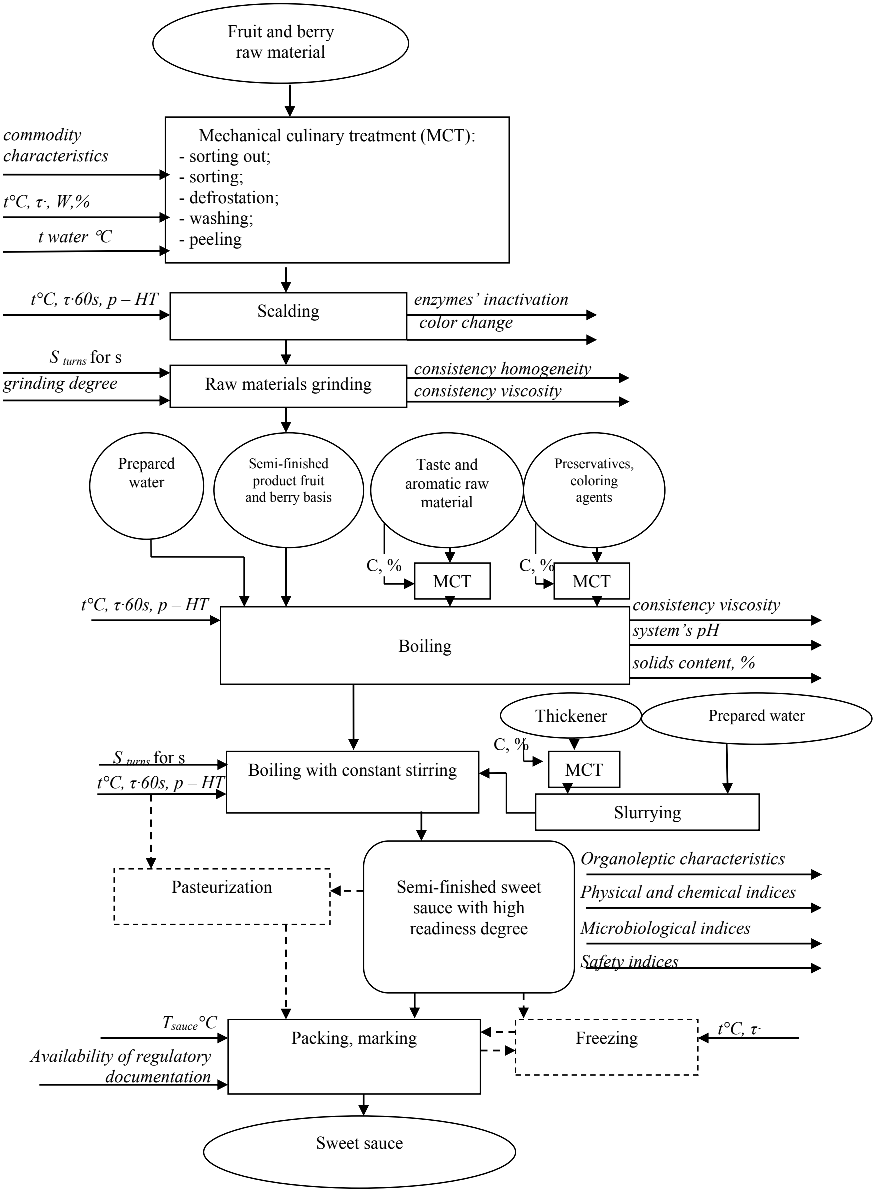


Figure 1.2. The technological process model of sweet sauces production

The need to regulate the properties of dispersed systems and to control the structure formation processes determine the specificity and patterns of change in the viscosity of model systems which form the sauces' consistency.

Most of the sweet sauces have consistency from liquid (syrup) to thick, paste or gel-like (toppings). The problem of sauces' colloidal systems stability providing can be solved by introducing FTI, the heat treatment influence to the solids accumulation and it allows developing a wide range of sauce products for meeting the demand of a wide range of consumers.

It should be noted that the assortment of sauces is formed mainly under use of different flavors, new structure-forming ingredients, technological operations.

These data indicate that with rather limited assortment of sweet sauces, they are characterized by short shelf life. The above is determined by the lack of scientific basis for the sweet sauces production and dictates the need to create new types of sauces, which would consist of available natural ingredients and which would have stable technological properties, organoleptic, physicochemical, structural and mechanical properties in the process of production, sale and storage.

1.2. Analysis of existing ways the stability of the sweet sauces dispersed system providing

The important condition for obtaining finished products with target indices is the prediction of behavior and efficiency from the interaction of individual components of the recipe mixture in the technological flow [33].

Food products (culinary products) as disperse systems can be homogeneous or heterogeneous [41–45]. Sweet sauces are multicomponent system which is subject to significant changes under technological factors activities. Important indicator of the sauces' quality is consistency; it is complex multifactorial indicator, the formation of which depends on the colloidal state, the dispersion degree, etc.

The complexity of colloidal stability providing is defined as a feature of the recipe composition (acidic medium, the presence of grinding fruit and berry raw material particles, etc.), and changes in the recipe mixture during processing, storage, use.

According to the definitions of [42; 47; 51] under the stability of the dispersed system is understood the constancy in time of its state and basic properties: dispersion, homogeneous distribution of particles of the dispersed phase in the volume of the dispersion medium and the nature of the interaction between the particles. The following types of dispersed systems stability are distinguished:

– aggregate resistance is the ability to keep the size of the dispersed particles (dispersion) unchanged over time, that is to counteract the coalescence;

– kinetic stability is the ability of the system to keep the dispersion of particles of the dispersed phase in the system volume unchanged over time, that is to counteract the leakage or deposition of particles;

– phase stability is the ability to keep in time the nature of the interaction between the dispersed particles, which is important for the systems where the dispersed particles interact (agglomeration, flocculation).

Understanding the factors which destroy consistency is very important for the substantiation and control of sauce technology [41-45]: mechanical or temperature effects; solids amount, presence and efficiency of consistency regulators use, pH value, electrolytes' effect.

One of the classic methods of the dispersed system destruction preventing is solids content increasing. This approach is most commonly used in the canning industry for the production of viscous, thick or gel-like products with solids content of 65-70%. The main disadvantage of concentrating solids by boiling is the reduction of nutritional value of products, quality control complexity, and the inefficient use of energy resources, which is economically impractical.

The solving the problem of dispersed systems stability is facilitated by the introduction of thickeners which bind fluid and increase the system viscosity. Analysis of information sources [25; 27; 46] proves that this approach has its advantages and disadvantages: on the one hand, the use of thickeners shortens the technological process duration compared to boiling. But the choice and substantiation of the thickener type should be based on certain organoleptic effects obtaining.

It is known that the dispersed medium of the sauce is an aqueous solution of monosugars, minerals, organic acids, in the volume of which the dispersed phase is distributed in the form of solid particles with a size of 30 – 150 μm [41; 47].

Water is bound under introduction into the liquid food system of the stabilizer (thickener) in the process of food preparation, and the result is mobility losing by system's solid particles, the product consistency changes, and the viscosity increases.

The food technologies development provides of the food additives industry formation, which, on the one hand, significantly simplifies the technological process, and on the other – causes withdrawal of traditional ingredients from the technological cycle [47; 48].

The practical application of FTI is well ahead of the scientific substantiation, which leads to a number of problems with their use in the production of products, its quality and safety, and thickeners choice and recipe mixtures preparation are carried out mainly empirically [19; 25; 46; 49–52]. The above mentioned dictates the need for scientific substantiation of FTI choice for their further implementation into the practice of the industry's enterprises.

There are general requirements to the functional properties of thickeners: the degree and speed of swelling, solubility, ability to stabilize liquid dispersion systems, resistance to the effects of destructive factors [23; 35; 46]. One of the main requirements to thickeners is the ability to thicken and structure the system in the presence of various nutrients, that is, the «universality» of the thickener, regardless of the food system composition.

Also important factor in the sweet sauces production technology is the characteristic of dispersions: viscosity, durability, thickening temperature, tendency to syneresis in the production and storage processes, ability to sorb and desorb aromatic substances and coloring agents, thermomechanical properties, rheological properties constancy.

Food ingredients of polysaccharide nature are represented by a wide range, however the results of information systematization and experience of food productions operation show that the most practical application was obtained by starches.

The use of native starches is limited because of their physical, chemical and functional and technological properties [35]. Most native starches (potatoes, grains) contain up to 25% of amylose, and food products with their use as thickeners and gel-forming agents are characterized by low technological stability and show pronounced tendency for syneresis [53].

The problem of stability providing, «aging» of starch pastes and gels preventing is key for food products (including long shelf life, frozen). Structure compaction, water releasing, turbidity increasing, change of organoleptic characteristics of foodstuffs are negative consequence of the starch retrogradation process [54; 55].

Native starch grains are also inclined to breakdown under technological factors influence (temperature, pH, mechanical action), which causes decreasing of food systems viscosity and consumption properties.

Significant disadvantages of the most native starches use in food products is the taste of «raw grain». Native grain starches (corn, wheat, rice) form opaque pastes, which is limiting factor in many technologies in terms of the desired products' appearance forming.

The use of low-amylose corn starch provides local gel forming [35; 51; 56–59]. Thus, the low stability of starch pastes and gels, their lability to temperature, mechanical action, acidity and ionic strength, taste characteristics limit the use of native starches as thickeners and gel-forming agents in many food technologies.

The properties and mechanism of gelatinized starch dispersions stabilization have been noted in large number of experimental works and analytical reviews [53–55]. Formulated theoretical propositions about the properties and state of starch are presented in the works of M. Rikhter, M.M. Trehubov, A.I. Zhushman, V.S. Hriuner, N.P. Kozmina, N.H. Huliuk, L.V. Babichenko and others.

But today, practical research and development of new FTI are aimed at increasing the efficiency and expanding the technological potential of their use, the technology implementation effectiveness.

The regulation of the physical and chemical and functional and technological properties of native starches is achieved by their chemical, physical and enzymatic modification, which leads to significant expanding of their application sphere [35].

There is a wide range of modified starches in the market that, depending on the method of modification, are adapted to particular process of the product. However, the substantiation of the recipe composition of sweet sauces should be made with taking into account the specific properties and functions of modified starches, which are realized in the technological flow, and based on the aspects of their use.

FTI market monitoring has shown that the vast majority of technologies is based on the use of chemical modification starch in food products technology.

According to regulatory documentation [60], modified starches are starches which have modified properties as a result of physical, chemical, biochemical or combined treatment.

The basis of various methods of chemical modification is the need to obtain certain properties by changing the molecular structure of starch polysaccharides (controlled modification of hydrogen bonds), which allows increasing the functionality of starch in food technology and to expand the sphere of its use.

For example, starches-thickeners have high characteristics' stability, create controlled viscosity level, provide «short» creamy consistency and feeling of fullness, allow production costs reducing [61–65].

The analysis of modern scientific data [66–71] shows that the following types of chemical treatment and their combinations are used for modified starches obtaining: esterification with acetic and succinic anhydride, mixture of acetic and adipic acid anhydrides, octenyl succinic acid anhydride; treatment with phosphoryl chloride, trimethophosphate and sodium tripolyphosphate with esters forming; esterification with propylene oxide for simple ethers forming; acid modification with hydrochloric and sulfuric acids with hydrolysis products forming or potassium permanganate and sodium hypochlorite; oxidation by sodium hypochlorite.

The main advantage of chemically modified starches is their resistance to certain destabilizing technological factors (high-temperature processing modes, acid and mechanical effects), as well as providing the stability of the food products structure during their storage and consumption (in the freezing-thawing cycle, cooking in microwave ovens, etc.) [35; 47; 51; 60].

Phosphate starches (E1410, E1412, E1413) provide the consistency which is more resistant to decomposition, action of temperature, acids, freeze-thawing cycles compare with native starches using.

Acetylation (for the chemical modification of E1420 starch) causes slowing down of starch aging but starch becomes less resistant to heat, mechanical action and acids.

Acetylated crosslinked starches (E1414, E1422, E1423) are most commonly used for thickening and stabilizing ketchups and other sauces.

The ether of starch and the sodium salt of octenyl succinic acid (E1450) is characterized by pronounced emulsifying and foam stabilizing properties, so it is used in the production of mayonnaise as an emulsifier and emulsion stabilizer.

Along with the numerous advantages of modified starches, there are a number of disadvantages which affect the formation of technological limitations in their use [35; 73–75]. Thus, oxidized starches tend to darken through the temperature or during storage [35; 76]. Starch ethers and esters are used as thickeners for the preparation of fruit fillings. The introduction of chemical radicals into the starch structure increases the transparency of the paste and the stability during storage, mixing, heating, freezing-thawing and low pH values. Most types of modified starches belong to the crosslinked subset. The crosslinked starch flour paste is more viscous, has «short» texture, resists to various external influences such as high temperatures, prolonged heating, low pH values, mechanical loads [61; 64; 67; 76].

Today, epichlorohydrin can be used to produce cross-linked starches, which is unacceptable because of the established carcinogenic effect of chlorohydrin on the human body (distarch-glycerol) [35].

Particular attention should be paid to the formation of requirements to sauces from the consumer's point of view. Undoubtedly, despite chemical modification, starches are safe additives which are allowed for use, but their use and food additive status reduce consumer loyalty and limit their use for certain categories (for example, baby food).

Enzymatic modification is used for obtaining amylolysis starches with amylolytic enzymes use – amylases (α- and γ-), which break the α-1,4- and α-1,6-glycosidic bonds of amylopectin.

The hydrothermal treatment of enzyme-modified starches produces low-viscosity and high solids content flour pastes, which during cooling turn into strong elastic gels. They are used in filler technologies for soups, sauces, etc., as gel-forming agents – for fruit chewing candies, coating components.

However, analysis of existing technological processes of food production with modified starches use shows that the parameters and functions of such food systems as sweet sauces, where, on the one hand, the system's properties (pH, white sugar presence, certain content of solids, etc.) are important, on the other hand, it is processability with taking into account acid and thermal stability of the sweet sauces in the technological flow, cannot be fully implemented during their use and determine the expedience of research and scientific substantiation of alternative types of starch.

The above mentioned is prerequisite for the search for functional ingredients which, under use in technological systems, provide the implementation of functional and technological properties for obtaining sweet sauces with specified consumer properties. Scientific researches are aimed at developing fundamental and applied aspects in the field of creation and use of non-toxic materials, in particular starches, is becoming relevant in this direction. The formation of their properties is based on the innovative approaches without chemical modification use. On the base of scientific researches analysis, the possibility of creating the food system structure with starches use is determined, it involves their functional activity increasing because of monodisperse grains ranking [62; 68; 72].

Physical modification of the polymers' properties can be achieved both at the ingredients' obtaining stage and during the technological process. As to starch, the physical modification takes place in the technology of cold-swollen starches, porous starches which are obtained during cryolite (freezing, thawing) or extrusion, as well as amylolysis starches which are obtained during intensive mechanical processing – mechanolysis [75].

Physical modification is used for obtaining swollen (pre-gelatinized) starch and is carried out by wet-thermomechanical treatment of starch on roller, spray dryers or extrusion units, which provide rapid starch gelatinization and subsequent drying of the flour pastes. Such processing destroys the natural structure of starch grains, which is not accompanied by their destruction, and the starch acquires the ability to swell and dissolve in cold water.

Swelling starch has widespread use as structure-forming agent and filler with high moisture-retaining power. This group of modified starches includes starch which is obtained by wet-heat treatment of starch suspension at high temperature or as a result of extrusion treatment. This modification type provides the starch with increased ability to hydrate and swell in cold water.

It is known from literary sources [77–80] that increase of swelling degree for different origin starch occurs under suspension heating to certain temperature (gelatinization temperature), the values of which are within wide limits.

Today, swelling starch is obtained in various ways: by native starch extrusion treatment and in the conditions of roller dryer. The starch suspension is dried in thin layer between two surfaces which are heated to 40…60°C until moisture removing for providing increased moisture absorption properties.

The main disadvantage of physically modification starches, which are obtained by extrusion drying, is the damage of starch grains in the fine grinding process, which causes inhomogeneous gelatinization process.

«Ingredion» companies group [81; 82] produces a wide range of innovative starches «Novation» without E index, which are characterized by the highest technological stability and maximum stability. «Novation» starches are declared as ingredients which form and provide a certain structure in wide technological range of different products (sauces, soups, fruit fillers, dairy products) under intense mechanical and thermal effects. These types of starch comply with EU Regulation 834/2007 and therefore can be labeled as «organic» [83].

The modern production method of «Novation» series starches is starch suspension heating to gelatinization temperature with minimum ripening time and subsequent spraying in the dryer. The starch grains are intact and unbroken, as under extrusion process. This modification starches have the features of classic starches which can bind moisture.

The destruction of starch grains occurs under extrusion effect. It proves the reduced resistance to mechanical impact, as well as the retrograde activity, which makes use these grains in the technological cycle impossible.

The important aspect is studying the morphological structure during developing modern technologies for modified starches, because the size, shape, surface character and grains size distribution can largely determine the quality of the starch and affect on their physical modification process.

Physical modification of «Novation» series starches consists in the specificity of the microstructural characteristics of starch grains, namely their shape, sizes, which have monodispersity [80–86]. The monodispersity of physical modification starches is almost the same size of starch grains. The monodisperse system of starch grains has the form of sharp peak with rather narrow system [87]; they can be both terminal states of substance – granules-grains of different sizes and phase states, and dynamic structures – coherent grain flows which are arranged in space and time.

Starches physical modification presupposes the increasing their functional activity and environmental safety by creating grain structure in monodisperse ranking.

The basis of starches size sorting physical modification is the idea that the physical and technical properties of starch can be controlled by starch grains fractionation, size and structure. Physical modification provides not only uniform swelling and starch grains gelatinization, but also distributes the ingredients in the dispersed medium.

Study of physical and chemical bases of dispersion thickening and modern technologies for physical modification starches obtaining allows predicting the perspective of their use in the sweet sauces technology.

PART 2
THEORETICAL AND EXPERIMENTAL SUBSTANTIATION OF TECHNOLOGICAL PARAMETERS OF OBTAINING FLOUR PASTED STARCHY DISPERSIONS AS SWEET SAUCES STRUCTURAL BASIS WITH PHYSICAL MODIFICATION STARCHES USE

2.1. Theoretical background for the sweet sauces technology development with physical modification starches use

Under analysis of the current state of food production development within the capacities of restaurant business enterprises, food and processing industries with taking into account the innovativeness of new and already implemented in practice economically efficient competitive technologies, it should be noted that today the range, composition, food products properties are subjects to significant changes accordingly to a number of requirements. These requirements, in view of the existing information systematization, are the cornerstones where food producers and the final consumer use completely different characteristics for requirements forming.

Analytical literature review, FTI market monitoring, comprehensive tasting assessment show the expediency and advantages of different types starches use in the sweet sauces technology, which allow obtaining a wide range of products with controlled structural and mechanical, physical and chemical and organoleptic characteristics which meet the modern quality requirements.

Food products with native starches which are used as thickeners are characterized by low technological stability and show pronounced tendency for syneresis because of the peculiarities of the native starches chemical composition and morphological structure. Native starches also have a number of use restrictions, which primarily consist in the low thermal and acid stability (during production) and short storage periods.

It is known that the heterogeneity of the starch grains size characteristics in the native starch, the presence of structural anomalies in the form of different inhomogeneities of the grain packing is the cause of the gelatinized starch dispersions (GSD) formation with heterogeneous volume structure.

Under different solubility, the low molecular weight starch fraction – amylose, as less hydrophilic forms the solution, which is essentially a sol that will separate from the solvent by the amylopectin micellar structure. The instability can be caused by the uneven distribution of free energy, which will be especially apparent in the case of starch with polydispersed characteristics.

According to theoretical studies, it can be stated that both the dispersion of the starch and the structure and grain packing density determine its behavior during the technological process. It should be noted that the duration of GSD existing in the equilibrium state under the use of starch grains with different dispersion will be significant because of the free energy maxima probability. On the base of the above mentioned, it is possible to speak about the expediency of starch using with uniform particle size distribution, and from the point of view of the systems' stability providing – starch grains should be clearly dispersed.

Modified starches are actively used; depending on the type of modification (chemical, physical, enzymatic), they have new technological properties. But the use of partially retained chemical reagents which belong to the group of food additives with E index and are quantitatively regulated, limits their use in baby and dietary food, organic products creation and determines the expediency of finding and scientific substantiation of starches' alternative types.

Because of innovations in the starches and starch products production, along with classic types of native starches, new types with optimized characteristics have been created. The implementation of physical modification starches in technology requires the study of the morphological structure (size, shape, grain surface nature, grains distribution), the influence of technological factors, etc.

The requirements are formulated, under which starch as a thickener can be used in the composition of sweet sauces on the base of fruit and berry raw material, regardless of the raw material type from which it is produced: starch grains monodispersity; low amylose content with taking into account the mechanism and physicochemical processes, which cause resistance decreasing at low pH values (2,0 – 5,5), mechanical effect, heat treatment, storage of sauces at low temperatures.

Data generalization allows forming scientific and practical concept for the sweet sauces technology development (table 2.1).

Table 2.1. **Scientific and practical concept of sweet sauces technology development**

Index	**Characteristic of sauces' indices**			
Groups of sweet sauces	**Dressing**	**Toppings**	**Dip, toppings**	
1	2	3	4	5
Purpose of use	Seasoning and combination with different products, semi-finished products	decoration a dish, beverage, or culinary product during preparation for sale	dip – consumption of snack products by «wetting»	toppings – dough base stuffing, filling sweet and curd dishes
Physical and chemical indices: – *effective viscosity, (Pa·s)(γ=50s⁻¹)*	0,30±0,01	1,50±0,04…2,07±0,06	3,07±0,09	3,50±0,10

Continuation of table 2.1.

1	2	3	4	5
Technological properties	stability under conditions: – the use of fruit and berry raw material at pH ≥ 3,0 values; – short-term or long-term storage (no less than 90 days; t=1…6°C); – mechanical effect of different intensity (from 1000 to 1500 s^{-1}); – thermal effect in the reheating process in the composition of culinary products, confectioneries (t>100°C); – freezing process at -18±2°C temperature, thawing			
Organoleptic characteristics: *– appearance and consistency*	homogeneous liquid, spreading rapidly on the horizontal surface	homogeneous viscous, homogeneous or heterogeneous (including filler particles) with a «long» texture	homogeneous or heterogeneous (including filler particles) with a «short» texture	
– color	volume homogeneous, time stable, meets the color of fruit and berry raw material			
– smell, taste	expressive, balanced, moderately stable, characteristic of fruit and berry raw material			
Purpose indices	lack of food additives with E index			
Safety indices	according to the requirements of this product group			

We used «Novation» series of physical modification starches for the sweet sauces technology. These starches can structure sauce's consistency, have stable viscous behavior during the cooling, reheating, freezing-thawing cycle and storage.

The choice of starches for the study was based primarily on consumer requirements and healthy food tendencies, technological and economic aspects of production and use by restaurant business enterprises and food industry.

2.2. Study of rheological and physical and chemical properties of starches

The technological aspects of sweet sauces obtaining are based on the creation of time-resistant colloidal systems with predetermined organoleptic characteristics and nutritional value, variable shelf life. One of the prerequisites for sauces obtaining is the structure-forming ability, which determines the structural and mechanical properties of the final product.

There is a lot of analytical information available now about the range and properties of starches (native and modified starches). Typically, these characteristics include general guidelines for the use of starch in the specific food technologies. However, the scientific substantiation of the technology involves not only the use of «ready» recommendations, but also understanding of the essence of starches properties during the implementation of the «production – storage – use in the production's composition» cycle.

Growing conditions and type of starch-carrier, chemical composition, structure, grain-size and fractional distribution will significantly influence the design of the technological operations sequence, raw material preparation special features, the order of components' introduction and the formation of finished products quality indices.

The need to study the grain-size distribution of starch grains; amylose and amylopectin content in the composition of starches; rheological properties of SS and GSD; effect of technological factors on the structural and mechanical properties of the GSD were determined for technological parameters substantiation.

Today, the starch as a food ingredient in the food market of Ukraine is represented by sufficiently large number of brands, which necessitates the choice of the most effective one in view of its properties and implementation in the specific technological process.

Analysis of information sources shows that the properties of starches and their GSD have been thoroughly investigated by domestic [4; 26; 46; 51; 106] and foreign [8; 11; 21; 44; 54; 55] scientists. But under the presence of vast information array, the development of sweet sauce technology requires the determination of absolute values such as: viscosity, stability under the technological factors effect, storage duration, etc. They will form the peculiarities of the recipe composition and such technological features as the method of SS introducing into the fruit and berry base and structure formation conditions.

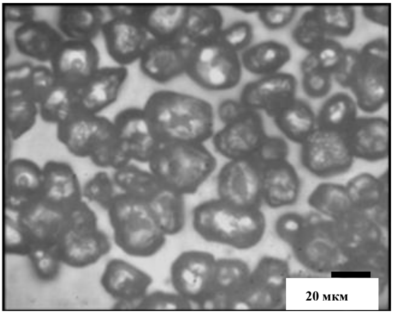
Six starch samples were selected for the study: wax corn starch «Prima» 600, tapioca starch «Endura» 0100, tapioca starch «Indulge» 3920, amylopectin corn starch, as control sample – potato and corn starches.

Microscopy is one of the research methods which allows starch grains identifying. It is known that starch granules have characteristic appearance and differ in size, shape, location and eyes appearance, cracks presence, etc. [107; 108].

Fig. 2.1 data show the results of starches microscopic studies, which can potentially be structure-forming agents in the technology of sweet sauces semi-finished products. SS in the aqueous medium were used (t = 20 ± 2°C) for the studies; it allowed the grain conglomerates identification.

Tapioca starches grains (1, 2) have oval or lenticular form, the fractional composition can be characterized as small- (12 – 13 μm) and medium-grained (16 – 25 μm).

Waxy corn, amylopectin, native starches grains (3, 4, 5), respectively, have slightly different shapes: multifaceted, irregular shape, which is typical for wax and ordinary corn starches. It is due to the conditions of grains formation and development: they are formed in the protein matrix at low humidity and are compressed during grain ripening [109 – 113].



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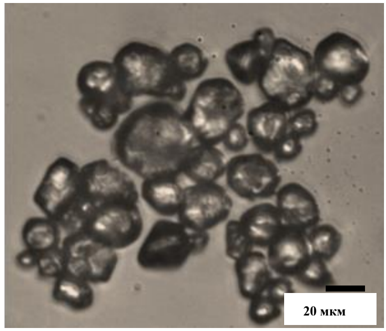

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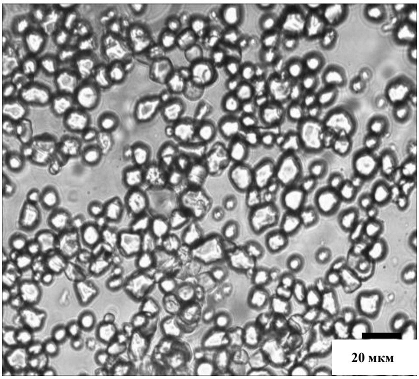

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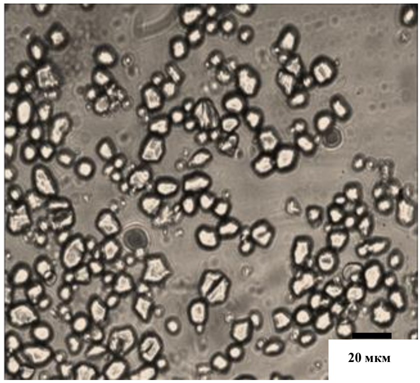

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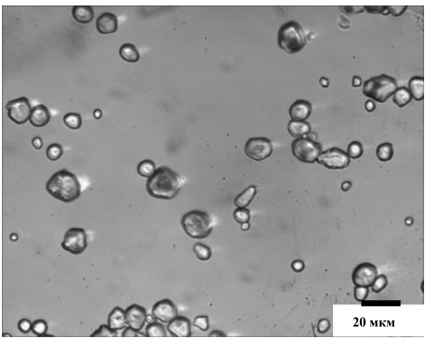

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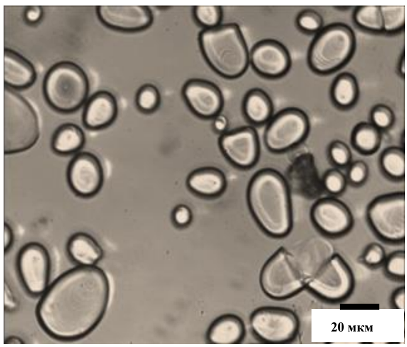


6

Figure 2.1. Micrographs of the starch systems (SS) with 40 times magnification: 1 – tapioca starch «Endura»; 2 – tapioca starch «Indulge»; 3 – wax corn starch «Prima»; 4 – corn amylopectin starch; 5 – corn starch; 6 – potato starch

Wax corn (3) and amylopectin corn (4) starches consist of small grains which have multifaceted shape. «Prima» starch (3) is characterized by less pronounced medium-grained fraction; it is characterized by highly dispersed grain distribution, namely, the most fractions consist of small similar shape grains. There are more medium- and fine-grained fractions in the amylopectin corn (4) starch.

Corn starch (5) is characterized by an oval grain shape, which is characteristic of starch from floury corn varieties, the fractional composition is finer-grained, and the monodispersity is practically absent under the condition of uniform distribution of the medium-grained fraction which has minimum fraction volume of about 30%.

Potato starch grains (6) are round and oval, and concentric stripes are present on their surfaces; it is typical feature of potato and tapioca starches, most of the grains belong to the coarse-grained fraction.

During the studies, we determined the volume part of starch grain fractions and constructed the grain distribution curves (according to the average size) and the volume part of their fractions (fig. 2.2).

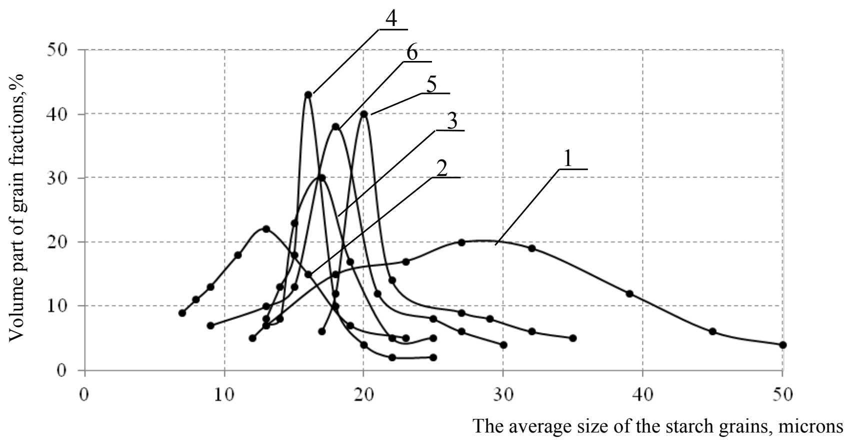


Figure 2.2. Distribution of starch grains by medium size for starches: 1 – potato; 2 – corn; 3 – corn amylopectin; 4 – wax corn «Prima»; 5 – tapioca «Endura»; 6 – tapioca «Indulge»

On the base of above mentioned, the volume part of grain fractions plays an important role in the GSD rheological characteristics forming. Thus, corn starch (2) has the starch grain fractions volume part of 13 ± 1 μm and it is about 22%, and this grain size belongs to the medium-grained fraction. Corn amylopectin starch (3) is represented by medium-grained fraction (17 ± 1 μm), which is about 31% by volume. Thus, it proves that corn starch and amylopectin corn starch are polydispersed according to the grain distribution.

About 20% of the potato starch fractional composition is medium-sized grains from 23 to 32 microns, the coarse-grained fraction is from 32 to 50 microns, it is 10% in volume fraction.

The average grain size of «Endura», «Indulge» (5, 6) tapioca starches is different. Thus, the volume fraction of «Endura» starch grains of 20 ± 1 μm is more than 40%, and the volume fraction of «Indulge» starch grains of 18 ± 1 μm is 38%. It is known [3; 114] that small grains (1 – 10 microns) contain more amylose and are more resistant to acid and enzymatic hydrolysis.

Special feature of wax corn starch «Prima» (4) is more clearly defined high monodispersity, that is, about 43% of the grains have size 16 ± 1 microns. Microscopic studies data (fig. 2.1) show that starch has high monodisperse grain ranking, which provides the uniformity of the swelling and gelatinization processes.

Analysis of starches' microstructural characteristics allows previously assessing and forecasting their changes in the production technological process of sweet sauces. However, different granulometric composition can significantly affect on the further properties during the technological process. Unlike other biopolymers, the molecules of most starch types consist of two fractions: linear (amylose) and branched (amylopectin), which are heterogeneous according to chemical structure and differ significantly in properties [21, 115 – 118].

There are different hypotheses of the starch grains structural organization. Donald's model explains the formation of crystalline areas by co-crystallization of amylose macromolecules with amylopectin side chains [60; 119; 120]. According to Giddley, crystalline lamellae are formed by an ordered amylopectin fraction, and amylose chains form amorphous areas [121]. Recent studies support the hypothesis that linked amylose chains are distributed in both amorphous and crystalline lamellae, while some of them form one-dimensional structures in the crystalline area – «filaments», and have disordered structure in the amorphous part [121–123]. The presence of α- (1 → 4) -glucoside bonds, which form unbranched chains is common feature of amylose and amylopectin.

We construct the calibration curve (fig. 2.3), which determines the concentration of amylose in the starch samples and studies their fractional composition (table 2.2) on the base of amylose solutions optical density values.

Studies of the starch suspensions optical density show that they are characterized by different content of amylose and amylopectin. The absorption maximum is shifted to the left for corn amylopectin starch (3) and «Prima» wax corn starch (4), which corresponds to about 100% of amylopectin in their content.

The smallest amount of amylose is found in tapioca starches (5, 6), and the correlation between amylose content and grain size is weak. The colorimetric analysis results show that the amylose content in native potato and corn starches completely corresponds to the literature sources data [124 – 126].

It is better to use amylographic methods for swelling and gelatinization processes characterizing which can identify consistency dynamic changes depending on the temperature.

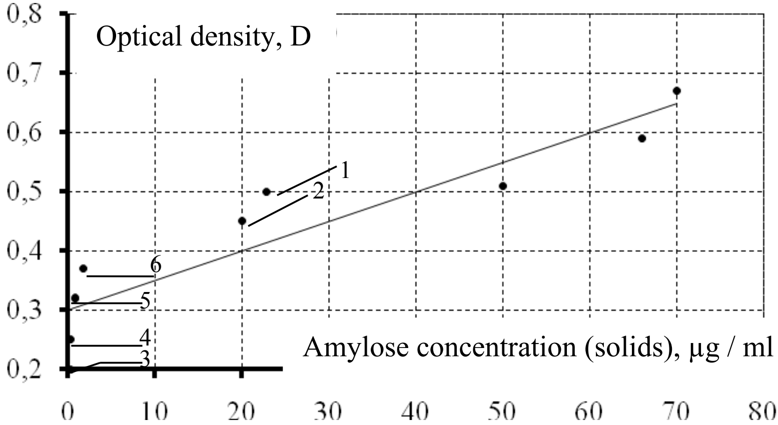


Figure 2.3. Dependence of optical density of iodine-amylose solution on concentration of amylose in SS on the starch base: 1 – corn; 2 – potato; 3 – corn amylopectin; 4 – wax corn «Prima»; 5 – tapioca «Endura»; 6 – tapioca «Indulge»

Table 2.2. **Amylose and amylopectin content in starches**

Starch	**Content, %**	
	amylose	**amylopectin**
Potato	20,0±0,6	80,0±2,4
Corn	22,8±0,7	77,2±2,3
Corn amylopectin	traces	99,0±1,0
From wax corn «Prima»	traces	99,0±1,0
Tapioca «Endura»	1,4±0,04	98,6±2,9
Tapioca «Indulge»	1,8±0,05	98,2±2,9

It should be noted that GSD are viscous and plastic thixotropic fluids for which the viscosity value is shear stress function. The studied systems thixotropy is shown by the presence of maximum and minimum viscosity local values, the ratio values of which determines the system resistance coefficient *($k = \eta_{min} / \eta_{max}$)* to external factors – temperature, acid and sugar (fig. 2.4, table 2.3).

It is found that GSD on the base of corn starches (curves 1, 3) have the maximum viscosity value (η_{max}) of 720–780 Brabender units and the minimum viscosity value (η_{min}) of Brabender110 ± 2 units. The viscosity decreasing (tending to $\eta_{max} \Rightarrow \eta_{min}$) indicates the degree of structural elements destruction under the influence of mechanical stress and thermolysis. «Endura», «Indulge» tapioca starches and «Prima» wax corn starch (curves 5, 6, 4) have virtually identical values of η_{min} and η_{max} (920… 1000 units of Brabender), which proves the stability of the GSD structure.

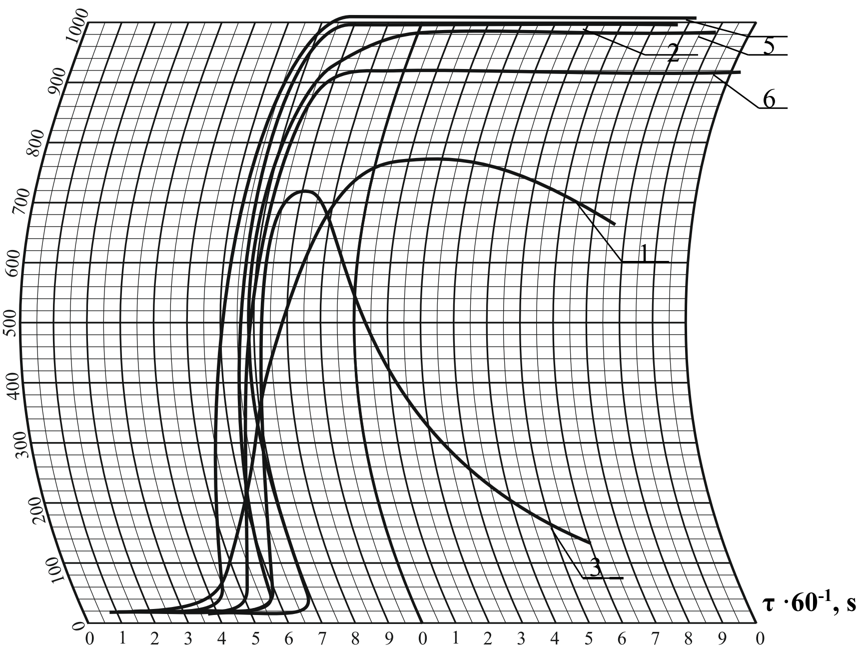


Figure 2.4. Amylogram of starch-based gelatinized starch dispersions: 1 – corn; 2 – potato; 3 – corn amylopectin; 4 – from wax corn «Prima»; 5 – tapioca «Endura»; 6 – tapioca «Indulge»

Table 2.3. **The rheological characteristics of flour pasted starch dispersions**

Starch	**Gelatinization temperature, °C**		**Gelatinization viscosity, Brabender Units**		**The relative stability coefficient $\frac{\eta \min}{\eta \max}$**
	initial	**final**	**η_{max}**	**η_{min}**	
Potato	72±2	96±2	780±2	660±2	0,84
Corn	67±2	73±2	1000±2	1000±2	1,0
Corn amylopectin	72±2	78±2	700±2	110±2	0,15
From wax corn «Prima»	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

«Endura», «Indulge» tapioca starches and «Prima» wax corn starch (curves 5, 6, 4) have virtually identical values of η_{min} and η_{max} (920… 1000 units of Brabender), which proves the stability of the GSD structure. Probably, it is explained by the fact that the grains with medium-grained monodispersed fraction (≈83%) equally swell and gelatinize.

The initial gelatinization for corn starches (native and amylopectin) occurs at the same temperature of 72±2°C, but the maximum gelatinization for corn amylopectin starch is observed at 78±2°C and lasts (3–4)·60 s, after this time it decreases. The maximal gelatinization for corn starch occurs at 96±2°C and lasts for (5–6)·60 s. Probably, it is explained by the fact that starches have polydispersed fraction (fine-grained – 43%, medium-grained – 57%). These grain sizes, especially the smaller ones, have high hydration ability and accelerated swelling factor compared to larger grains, which is explained by better interaction with water.

«Endura», «Indulge» tapioca starches and «Prima» wax corn starch have lower temperature (58…62°C) of gelatinization process starting. The temperature of maximum gelatinization is 68…72°C, the dispersion is characterized by viscosity values with maximum resistance coefficient of 1,0. Probably, it is explained by the fact that the grains with medium-grained monodispersed fraction (≈83%) equally swell and gelatinize in the distribution area.

Thermodynamic research methods, such as differential scanning calorimetry (DSC), are the most normative and accurate for determining the specific heat which is consumed by starch grains decomposition. The results of calorimetric studies of 1,0% starch suspensions which are subjected to heat treatment in the temperature range of 0…100°C, under excess pressure of 0,25 MPa are shown in fig. 2.5.

Thermodynamic studies of starch suspensions, which describe the initial gelatinization processes, show that the decomposition of starch grains is characterized by endothermic peaks, which consume the activation energy of moisture binding.

As it can be seen, the peak values of the specific heat clearly correlates with the values of initial gelatinization and they are 72°C for corn and corn amylopectin starches (2, 3), 67°C for potato starch (1), 60°C for «Prima» wax corn starch (4) and 62°C for «Endura» and «Indulge» tapioca starches (5, 6). The above mentioned results are the basis for substantiation of the minimum temperature at which the starch is gelatinized during sauces production.

The next stage is studying the process of starch gelatinization in combination with acid and sugar. The regularities of the starch gelatinization process under acid and sugar were determined (fig. 2.6). Such technological process parameters are determined: C_{starch} = 7,0%; $C_{citric\ acid}$ = 0,5%; C_{sugar} = 15,0% as a result of the system's functioning adequacy checking in the sweet sauces technology in model systems.

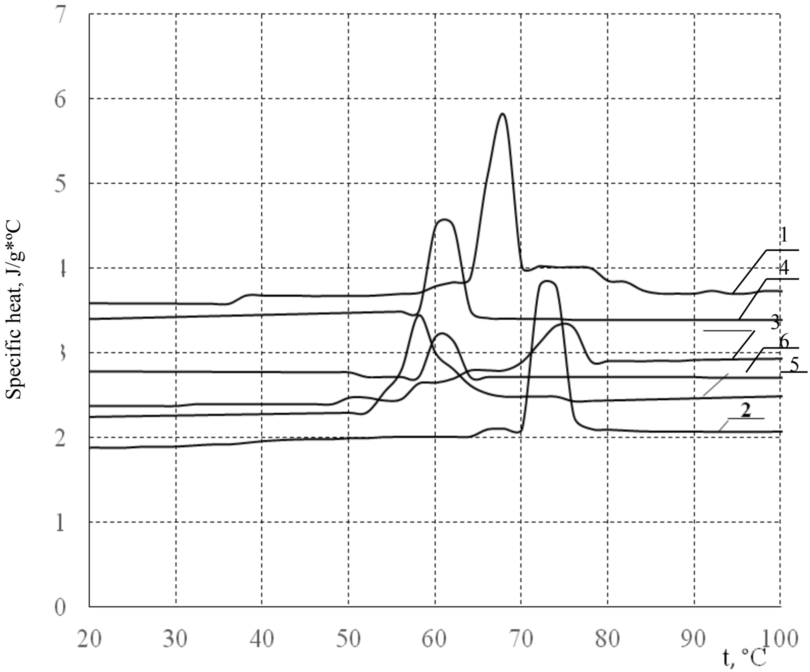
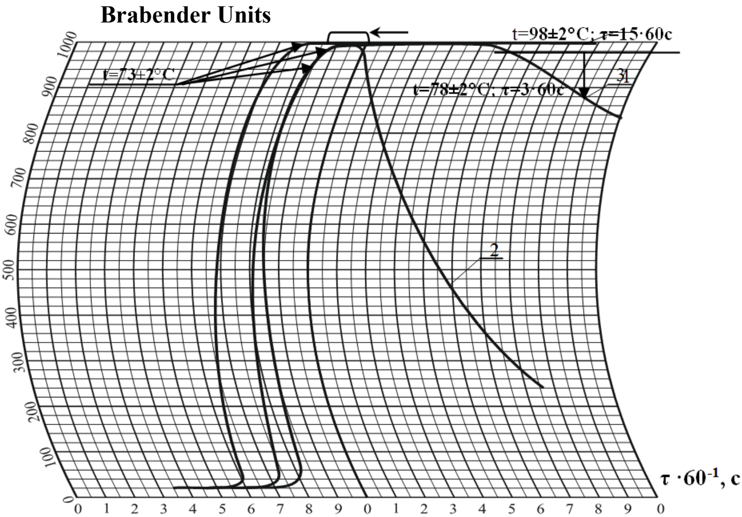


Figure 2.5. DSC curves for SS on the starch base:
1 – potato; 2 – corn; 3 – corn amylopectin; 4 – wax corn «Prima»;
5 – tapioca «Endura»; 6 – tapioca «Indulge»

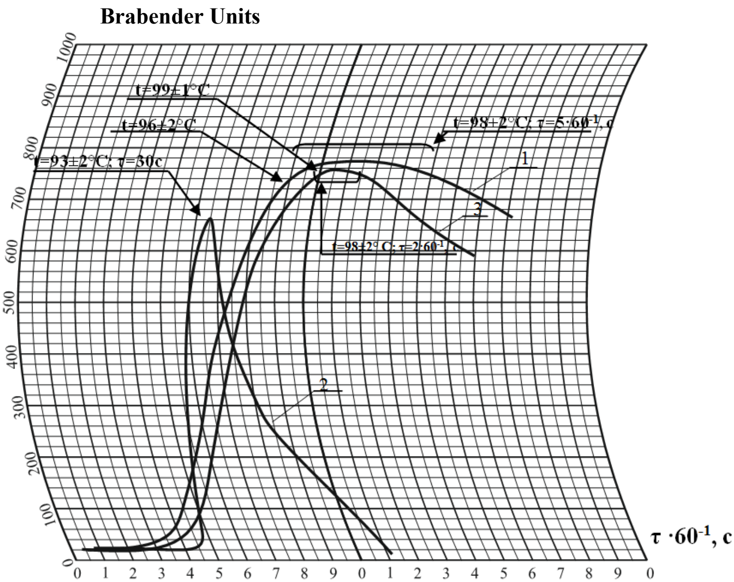
The study of the acids' influence on the formation and stability of GSD shows that GSD on the base of starch from waxy corn «Prima» and tapioca «Endura» is characterized by the most pronounced resistance.

The maximum viscosity for the wax corn GSD is 1000 ± 2 BU, the stability coefficient is 0,9. The maximum viscosity of GSD on the base of «Endura» starches is 840 BU, «Indulge» has the value of 960 ± 2 BU, and the stability coefficient is 0,8.

The viscosity of corn starch is significantly reduced. Thus, corn starch has the viscosity of 660 ± 2 BU and it lasts up to 30 seconds, the viscosity of corn amylopectin starch is 480 ± 2 BU, it lasts 10 seconds. The characteristic decreasing and instability of the viscosity indices are explained by the bonds breaking process between monosaccharides, i.e. reducing substances accumulation. It is also known that the presence of fine-grained fraction, which is sensitive to acids effect, may cause the starch grains destruction.

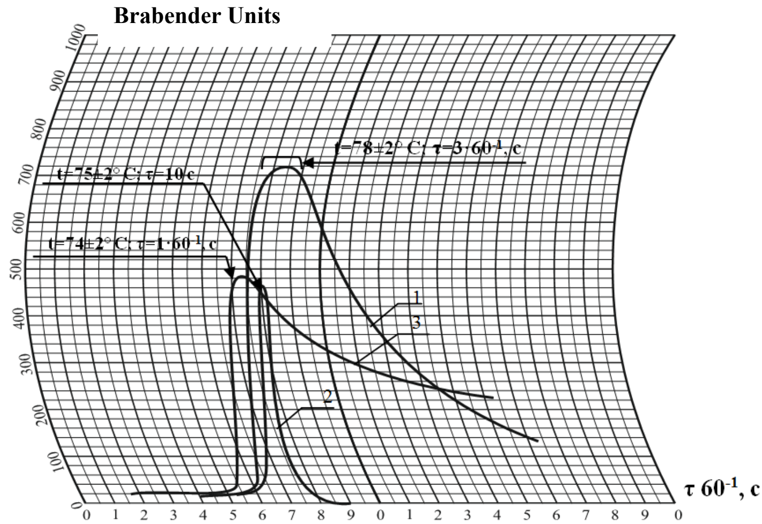


a



b

Figure 2.6. Amylogram of viscosity changes of GSD in the compositions:
1 – starch–water; 2 – starch–citric acid–water; 3 – starch–sugar–water;
a – potato starch; b – corn starch; c – corn amylopectin starch; d – wax corn starch «Prima»; e – tapioca starch «Endura»; f – tapioca starch «Indulge»



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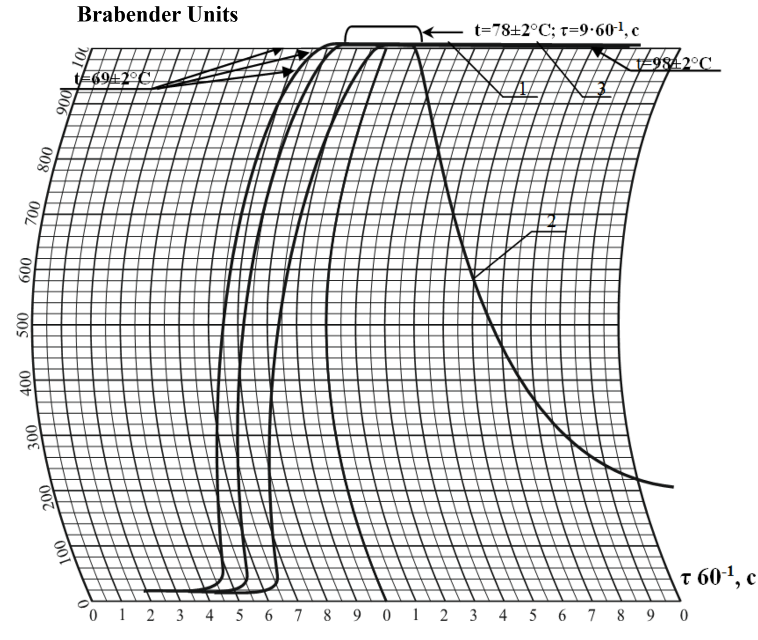
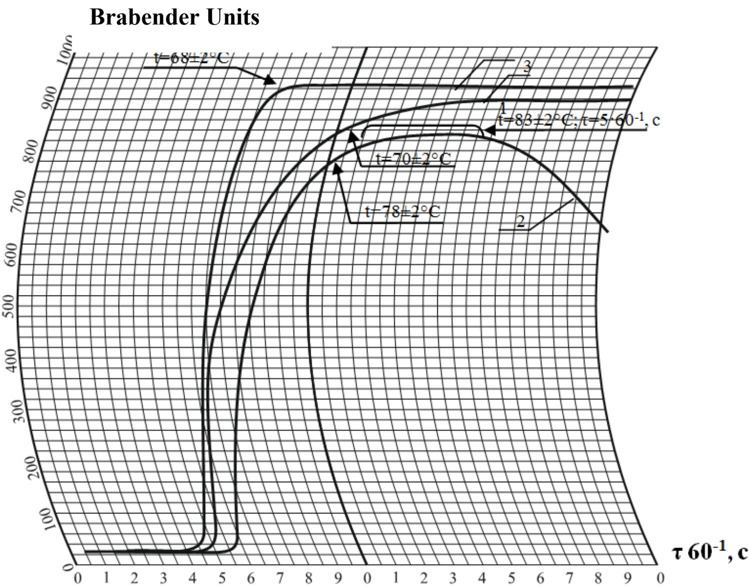


d

Figure 2.6., sheet 2



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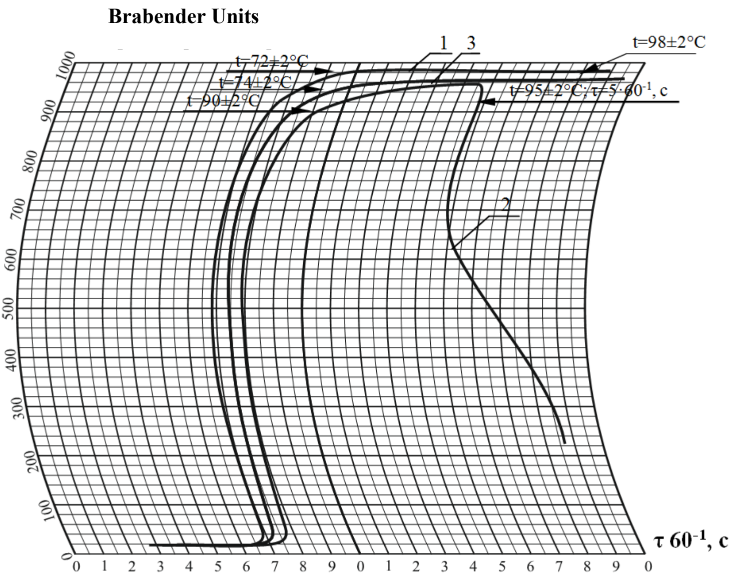


f

Figure 2.6., sheet 3

The introduction of sugars into the MS and their subsequent gelatinization show that under temperature increasing up to 98 ± 2°C for corn starch and 75 ± 2°C for corn amylopectin starch, the maximum viscosity is 780 ± 2 BU and 460 ± 2 BU respectively, after which the viscosity of the GSD rapidly decreases.

The maximum viscosity values of GSD on the base of «Prima», «Endura» and «Indulge» starches are stable and in the range of 980 – 1000 BU, and the GSD stability coefficient is 1,0.

Below we present the research results and determination of the water binding process regularities in model systems, because of the water state in the GSD determines the course of the colloidal processes complex at all stages of the sauce production and significantly influences on their storage duration.

For this problem solving, we use the method of pulsed nuclear magnetic resonance (NMR), which allows obtaining simultaneously information about the number of resonating nuclei (in our case, water resonating nuclei) and the nature of molecular mobility (water state) [50; 124 – 126]. The value which determines the mobility and state of the water in the system is T_2. It characterizes the time of spin-spin relaxation, that is, the time it takes to return the system to its original state. This time is determined by the conditions for penetration of hydrogen nuclei into the system. It is possible to assess water mobility degree in GSD and to determine the tendency of their changes depending on the recipe composition if T_2 value is determined. GSD stability was assessed under 20 ± 2°C temperature (table 2.4).

There is general tendency to reduce the spin-spin relaxation time by increasing the starch content from 5 to 8% for all model systems. Probably it can be explained by the fact that water becomes less mobile because of the concentration increasing of starch moisture-binding and moisture-retaining components, primarily amylopectin, which provides water activity decreasing and physical and chemical reactions speed.

Table 2.4. **The dependence of spin relaxation signal amplitude on the interval (T_2) between the pulses for the GSD samples on the base of studied starch samples**

Studied sample of GSD on the base of starch	Spin-spin relaxation time (T_2) under starch content in the systems, %	
	5,0	8,0
Potato	0,315±0,015	0,178±0,008
Corn	0,778±0,038	0,261±0,013
Corn amylopectin	0,307±0,015	0,169±0,008
Wax corn «Prima»	0,320±0,016	0,193±0,009
Tapioca «Endura»	0,671±0,033	0,248±0,012
Tapioca «Indulge»	1,520±0,076	0,184±0,009

Minimum pulse intervals are observed for GSD on the base of «Prima» starch. The time of spin-spin relaxation reduces in about 1,5 times in the case of starch concentration increasing from 5 to 8%. It may be explained by the peculiarity of its morphological structure – grains monodispersity, which provides uniform swelling and also causes larger volume of moisture absorption. Probably, soluble polysaccharide molecules are covered by hydrated shells, which increases their intermolecular volume, reduces diffusion rate during starch grains swelling.

Thus, the time (T_2) decreases in 2,7 times under concentration increasing from 5 to 8%, and the tendency to viscosity increasing is minimal for GSD on the base of «Endura» starch.

The change of the spin-spin relaxation signals intensity of the samples is the indicator of water structuring degree in the systems. It is possible to determine the magnitude of water structuring rate during all study period for each system under analyzing the change in the intensity of the spin-spin relaxation signals of the samples.

At the next stage of the research we consider that it is necessary to conduct a set of experiments for substantiation of the technological factors effect on the starch properties.

2.3. Study of the technological factors effect on the physical and chemical, structural and mechanical properties of the gelatinized starch dispersions

Numerous studies of the technological factors effect on the GSD viscosity establish that the trends are generally close, while the absolute values of the indices are in a wide range.

It is known that the most important characteristic of sauces is the viscosity, which depends on the type, concentration, properties of the main and additional components, technological process conditions. Therefore, it is necessary to determine the regularities of research subjects behavior for complex substantiation of the sweet sauces technology.

GSD are microheterogeneous systems in which the dispersed phase is swollen starch grains which are dispersed in the soluble fraction, mainly it is amylose fraction [121].

The interaction of starch and water polymers largely determines the structure and texture of food products. The starch swelling is caused by the amorphous areas plasticization and melting of the starch crystallites which form the cross-linking system [124; 127].

Changes in the effective viscosity of «starch-water» model systems are determined for starch type and content substantiation for sweet sauces thickening and stabilizing (fig. 2.7). From the first the solutions viscosity should be determined at different concentrations (2 – 8%) depending on the shear rate at constant temperature of 70 ± 2°C because of GSD are non-Newtonian fluids.

It is experimentally proved that starch content control allows creation of GSD with liquid dispersions properties (from 2,0 to 3,0%), medium thickness dispersions properties (from 3,5 to 8,0%) and thick dispersions properties (from 7,0 to 8,0%), which are fixed as the recipe composition parameters of sauces with variable consistency.

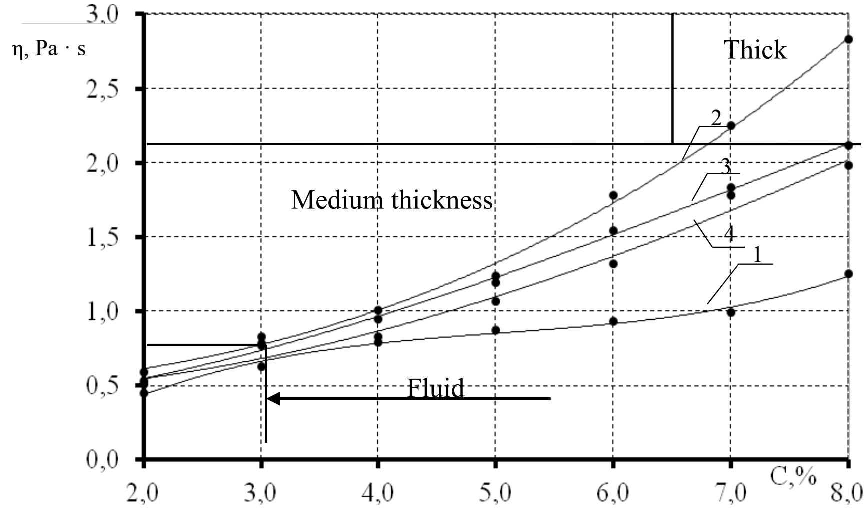


Figure 2.7. The dependence of the GSD effective viscosity on the starch content: 1 – corn amylopectin; 2 – wax corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca «Indulge» (under ɣ =50s^{-1})

Thus, it is determined that the viscosity of the GSD on the base of «Prima», «Endura», «Indulge» starches is higher than the viscosity of the GSD on the base of corn amylopectin starch.

Not only rheological but also organoleptic characteristics are important for further substantiation of starches' use possibility in the technological process of sweet sauces production (table 2.5).

As it can be seen, the corn amylopectin starch use can lead to inappropriate indices of sauces quality: «raw grain» smell and taste, transparent film formation during cooling.

Real food systems (semi-finished products, finished products) are effected by many factors which can significantly change organoleptic, rheological, physical and chemical and other parameters. It is necessary to study the starch systems changes in the «cooling-heating» cycle with taking into account sweet sauces production technology.

Table 2.5. **Characteristics of organoleptic indices of GSD with starch content of 7%**

GSD on the starch base	Organoleptic characteristics	Characteristic
Corn amylopectin starch	Appearance, consistency	Homogeneous dispersion, without lumps, viscous-fluid with pronounced fluidity
	Color	Light gray, transparent
	Smell	It is peculiar to this starch agent
Wax corn starch «Prima»	Appearance, consistency	Homogeneous dispersion, without lumps, viscous and elastic
	Color	Neutral, transparent
	Smell	It is peculiar to this starch agent
Tapioca starch «Endura»	Appearance, consistency	Homogeneous dispersion, without lumps, viscous and fluid
	Color	Neutral, transparent
	Smell	It is peculiar to this starch agent
Tapioca starch «Indulge»	Appearance, consistency	Homogeneous dispersion, without lumps, viscous and fluid
	Color	Light white, non-transparent
	Smell	It is peculiar to this starch agent

It is known that the starch pastes' cooling is accompanied by the occurrence of hydrogen bonds between molecules chains with gel formation tendency because of aggregates and partial crystallization origination. It may be accompanied by the finished products' consistency change (compaction, texture deformation, moisture release), which is unacceptable.

That is why we have studied the structural and mechanical properties of GSD with starch content of 7,0% at temperature of 70 ± 2°C, after cooling to temperature of 1… 6°C and reheating to temperature of 70 ± 2°C (fig. 2.8).

GSD thermal stability studies show that GSD on the base of «Prima» starch (2) are the most stable in the cycle «heating – cooling – reheating», their viscosity after reheating reduces insignificantly. The reheating of GSD on the base of «Endura» (3) and «Indulge» (4) starches is also accompanied by slight decreasing of viscosity – from 2,0 ± 0,04 to 1,9 ± 0,04 Pa · s and with 1,8 ± 0,03 to 1,7 ± 0,03 Pa · s, respectively. GSD on the base of corn amylopectin starch are non-heat-resistant, and their effective viscosity during reheating significantly reduces – from 2,1 ± 0,04 to 1,0 ± 0,03 Pa · s.

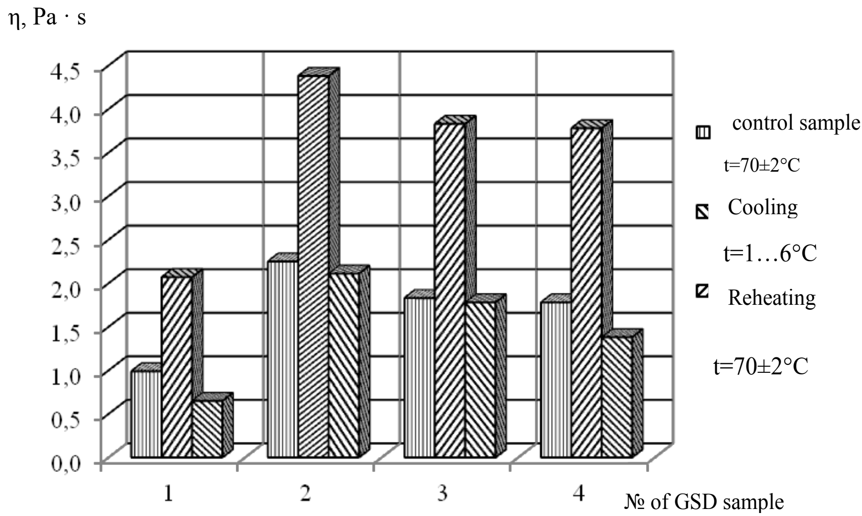


Figure 2.8. The effective viscosity dependence of starch-based GSD on the temperature (C_{starch}=7,0%): 1 – corn amylopectin; 2 – wax corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca «Indulge» (under ɣ =50s^{-1})

The effect of mechanical action may be accompanied by deformation, delamination, foaming or other changes. But the most significant change is the viscosity change which is associated with mechanical degradation of starch. Under mechanical effect GSD have a number of features which are related to their granular structure, fractional composition and pronounced viscosity anomaly [121].

The effective viscosity of GSD under the influence of mechanical action at different temperatures (70 ± 1°C, 4 ± 2°C) and the rotational speed of 1500 ± 5s^{-1} for 5 · 60 s, the shear rate of 50 s^{-1} were studied (table 2.6).

During GSD mechanical action the degree of their dispersion increases because of swollen starch grains mechanical splitting, which is accompanied by the water-soluble fraction content increasing.

But starch type and GSD temperature significantly affect on the mechanolysis degree. The GSD general trends at temperature of 70 ± 1°C are presented as follows: GSD on the base of corn amylopectin starch have the least resistance to destructive action (stability coefficient is 0,38). The sharp viscosity decreasing is associated with starch grains initial structure change, namely the destruction of starch dispersion physical fluctuation grid occurs.

GSD on the base of «Prima», «Endura», «Indulge» starches are characterized by higher stability coefficients (0,93; 0,81; 0,89 respectively), which indicates the prospect of their use in the sauces technology under mechanical action.

Table 2.6. **The research data of GSD effective viscosity under mechanical effect**

The name of starch-based GSD	GSD effective viscosity values (Pa·s) at temperature, °C					
	70±1			4±2		
	without mechanical effect (control sample)	under mechanical effect	stability coefficient	without mechanical effect (control sample)	under mechanical effect	stability coefficient
Corn amylopectin	1,20±0,02	0,50±0,01	0,38	2,10±0,03	1,0+0,02	0,48
Wax 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

Physical grid is formed by bonding between the particles after system's cooling and rest state holding. It is studied that mechanical degradation of cooled GSD shows similar trends but with lower stability coefficients. The viscosity value of GSD on the base of corn amylopectin starch, tapioca starch «Endura» will decrease almost by 2 times. GSD on the base of «Prima», «Indulge» starches are more resistant to destructive action (stability coefficients are 0,71 and 0,56 respectively).

The GSD effective viscosity results analysis allows concluding that there is viscosity decreasing with the stratification of GSD on the base of corn amylopectin starch under mechanical action effect.

There are also some differences in the dispersions' appearance, especially GSD on the base of corn amylopectin starch at temperature of 4 ± 2°C have more liquid consistency, which is accompanied by the dispersion fluidity.

Thus, the simulation of mechanical effect on GSD conditions shows that the systems on the base of wax corn starch «Prima» and tapioca starch «Endura» are the most stable.

It should be noted that GSD characteristics may vary depending on the system's composition and technological processes which take place, so we studied the effect of technological factors (temperature, pH, the presence of sugar in concentrations of 1–30% and acid in concentrations up to 0,4%) on model systems viscosity.

The effect of the various components on the properties of GSD is determined at constant shear rate of 50 s^{-1} with the effective viscosity curve construction. Since the viscosity for GSD under this rate is constant, any change in it will be determined by the technological factors effect.

As we continue to investigate the destructive factors effects, we determine that organic acids, sugar, and salt affect starch, which causes change of their consistency (viscosity).

In the literature data [128; 129] it is known that the conditions of starch crystallization depend on the pH value: even small acidity change can cause significant changes of GSD formation process.

The acidic taste (pH level) of fruit and berry sauces can be formed both by the use of acid-containing raw material (cranberries, cherries, citrus fruits), and the additional introduction of acids (for example, citric acid).

The acids which are used for process modelling are selected on the base of the following: hydrochloric acid is characterized by maximum hydrolysis constant (k = 100); citric acid has the highest hydrolyzing ability (k = 1,72) among other organic acids and is also one of the most common; acetic acid is the weakest among acids (hydrolysis property is k = 0,40), but it is part of many fruits and berries (apples, citrus fruits) [147].

Starch contains portion of additional agents which reduce the concentration of acid in solution. As the temperature rises, the rate of hydrolysis increases, and the temperature affects on chemical reaction rate and is characterized by the value of reaction rate temperature coefficient. The effect of different types of acids was determined by the effective viscosity (fig. 2.9).

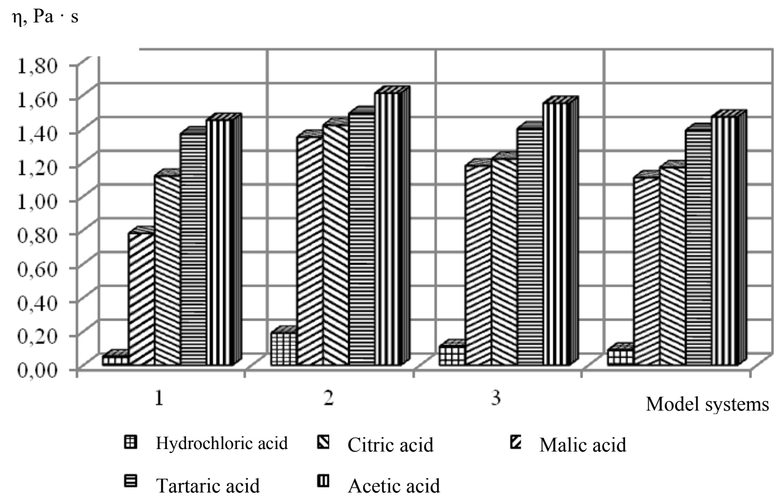


Figure 2.9. The effective viscosity dependence starch-based model systems: 1 – corn amylopectin; 2 – wax corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca «Indulge» (under ɣ =50s^{-1})

From the above-mentioned data, it can be seen that the viscosity value of GSD on the base of all starches significantly reduces, regardless of their concentration under introduction into the system of hydrochloric acid at concentration of 0,03 M. Probably, it is explained by the starch polysaccharides destruction, while decreasing of high molecular weight substances number and the accumulation of dextrins with different molecular weight occurs [128; 130]. It leads to the conclusion that the hydrolyzing ability of hydrochloric acid is the highest, which affects on the structural and mechanical properties of GSD.

GSD with weak organic acids such as malic, tartaric and acetic acids in their composition are characterized by stable values of effective viscosity.

On the base of obtained data it is established that GSD on the base of «Prima», «Endura», «Indulge» starches are the most resistant to citric, malic, tartaric and acetic acids; they show resistance during hydrolysis process, probably because of grains monodispersity. The effective viscosity of GSD on the base of «Prima» starch under interaction with citric acid decreases by 30,0%, with malic and tartaric acids – by 11,0%, with acetic – by 3,2%. It is experimentally proved that the viscosity of GSD on the base of «Endura» starch decreases by 41,1% under interaction with citric acid, by 32,0% under interaction with malic acid and by 7,5% under interaction with tartaric and acetic acids. The effective viscosity of GSD on the base of «Indulge» starch under citric acid effect reduces by 34,0%, malic acid – by 25,0%, tartaric acid – by 6,5%, acetic acid – by 2,0%.

The effective viscosity of GSD on the base of corn amylopectin starch under interaction with citric acid decreases by 50,0 – 55,0%, with malic and tartaric acids – by 30,0 – 35,0%, with acetic acid – by 25,0%.

We have determine that pH values of sauces is in the range of 3,0 – 5,5 under different recipe composition. Study data of the effective viscosity dependence on pH are presented on fig. 2.10; its reduction in the acidic direction is provided by the citric acid introduction (concentration is 0,5%) at starch concentration of 7,0%.

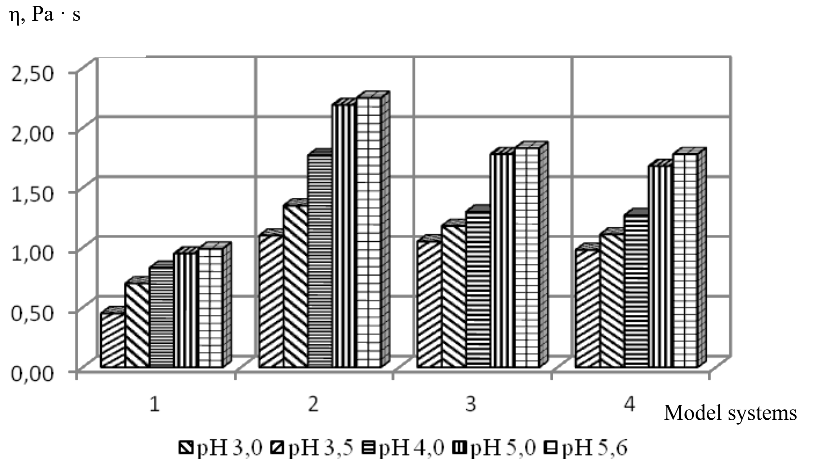


Figure 2.10. The GSD effective viscosity dependence on pH for starch-based GSD: 1 – corn amylopectin; 2 – wax corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca «Indulge» (under γ =50s^{-1})

Obtained data analysis allows to determine that the decrease of GSD pH causes decreasing the effective viscosity of all samples, which is explained by starch grains macrostructure change.

Significant drop of viscosity value in the case of pH value decreasing (in 2 – 3 times) is observed for GSD on the base of corn amylopectin starch. It is proved that GSD on the base of «Prima», «Endura», «Indulge» starches are more resistant to acids.

GSD on the base of «Endura», «Indulge» starches are characterized by stable viscosity values pH from 5,0 to 4,0, where GSD viscosity decreases from 1,60 ± 0,05 to 0,80 ± 0,02 Pa · c respectively.

Intense decreasing of the viscosity for GSD on the base of corn amylopectin starch occurs in the pH range of 5,55 – 4,50: from 0,95 ± 0,03 to 0,83 ± 0,01 Pa · s, after which sharp decreasing to 0,45 ± 0,003 Pa · s occurs. GSD on the base of amylopectin starch have rather liquid system according to visual studies.

The effect of white sugar on the gelatinization process and the properties of GSD is of practical importance during different textures sauces production. It is known that sucrose delays starch grains swelling in water because of its high solids content. Therefore, we consider that it is necessary to study the effect of sugar on the rheological characteristics of GSD for comprehensive substantiation of starches use in the sweet sauces technology. Sugar concentration (0 – 40%) is selected on the base of diagnostics of analog food products recipes (fig. 2.11).

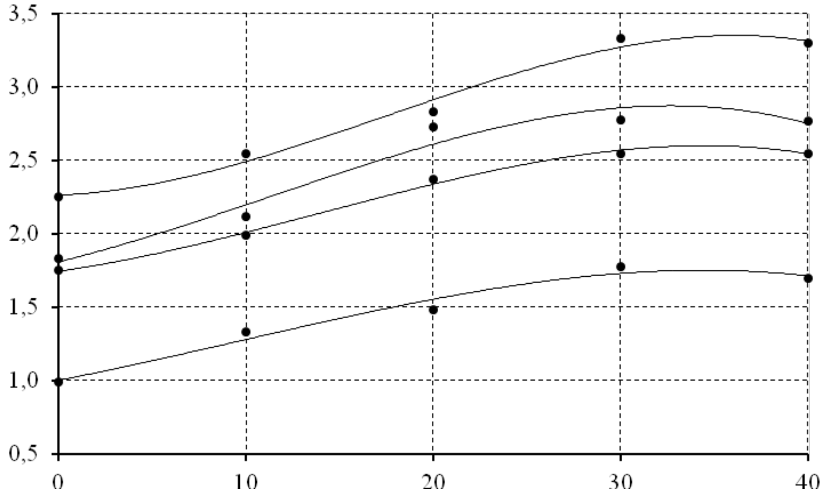


Figure 2.11. The GSD effective viscosity dependence on (C_s=8,0%) white sugar concentration for starch-based GSD: 1 – corn amylopectin; 2 – wax corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca «Indulge» (under ɣ =50s^{-1})

The general trends analysis shows that under sugar concentration increasing to 40%, gradual increasing of viscosity values for all model systems occurs, but their value has its differences depending on the starch type. Viscosity values increasing is observed with sugar content of more than 15% for all samples.

For GSD on the base of corn amylopectin (1) starch, the viscosity value gradually increases with white sugar concentration of 5,0 – 30,0%, and then its decreasing occurs. It can be explained by the dehydrating effect of sugar in the concentration range of 25 – 40%.

Intramolecular interactions which are result of molecules conformation changes cause the formation of supramolecular structure which precedes sucrose crystallization. Obviously, GSD destabilization is associated with starch polysaccharides solubility decreasing, aggregates formation and partial aggregation because of the hydrogen bonds formation between the amylose chains and linear fragments of amylopectin molecules. Sucrose, which is characterized by dehydrating action, intensifies destabilization.

Effective viscosity of GSD on the base of wax corn «Prima» starch, tapioca «Endura» and «Indulge» starches with 5 – 30% of sugar is characterized by increased values, probably because of the solids accumulation. All curves aligns under 30 – 40% concentration increasing; it proves the gel stability according to sucrose content and forms GSD yield stress.

Determining the rational values of the model structural base for sweet sauces for achieving the desired value of given product index is complex technological task and it is advisable to carry out its solution on the base of modern research methods, which primarily include mathematical modeling methods [147]. However, it is expedient to build the mathematical model of recipe development on the base of regression ratio with taking into account the complexity of the relationship between the input and output variables of the finished product, which makes it impossible to take full advantage of the basic physical and chemical laws and parameters uncertainty of the processed raw material.

The effect of different starches types on the GSD viscosity is studied. During the design of the experiment planning matrix, it was prematurely constructed randomly with random numbers use. The final version of the experiment planning matrix was obtained by coded below presented values introducing. The coded values were applied by relation: X_1=sugar concentration (-1 – 10,0%; -0,5 – 15,0%; 0 – 20,0%; 0,5 – 25,0%; 1 – 30,0%); X_2= pH values (-1 – 3,0; -0,5 – 3,5; 0 – 4,0; 0,5 – 4,5; 1 – 5,0); Y1=viscosity index for «Prima» starch; Y2= viscosity index for «Endura» starch; Y3= viscosity index for amylopectin starch (the effective viscosity values are presented in Appendix A) (fig. 2.12 –2.17).

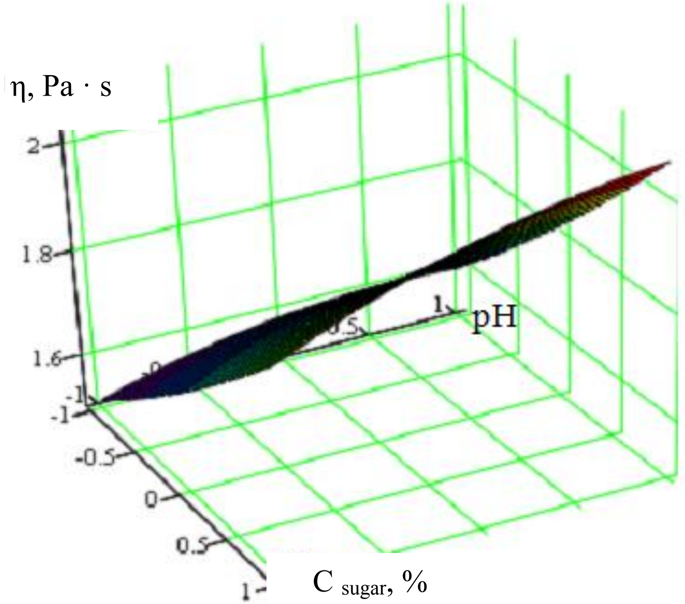


Figure 2.12. Mathematical model of response surface for model systems on the base of «Prima» starch

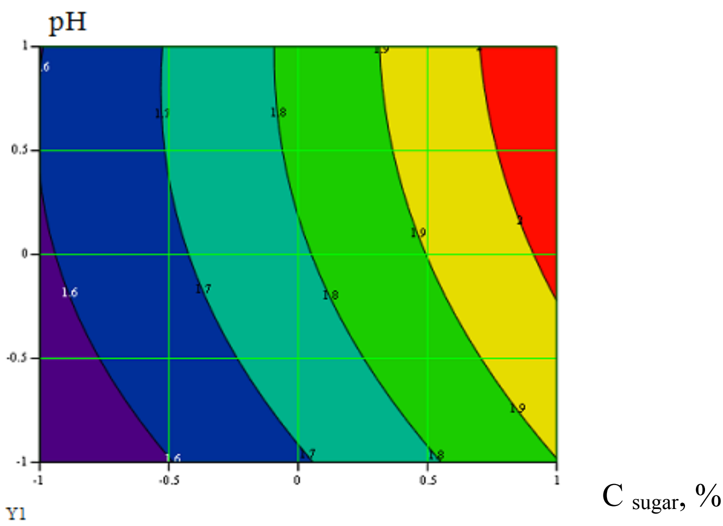


Figure 2.13. Maximum values of effective viscosity for model systems on the base of «Prima» starch

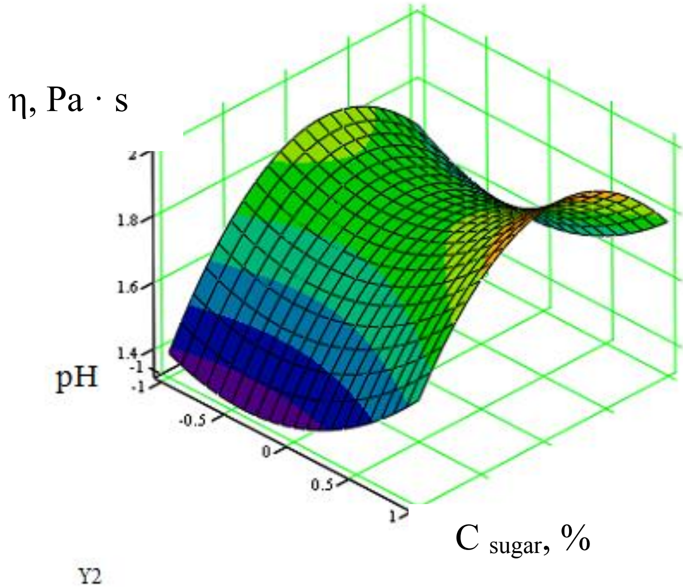


Figure 2.14. Mathematical model of response surface for model systems on the base of «Endura» starch

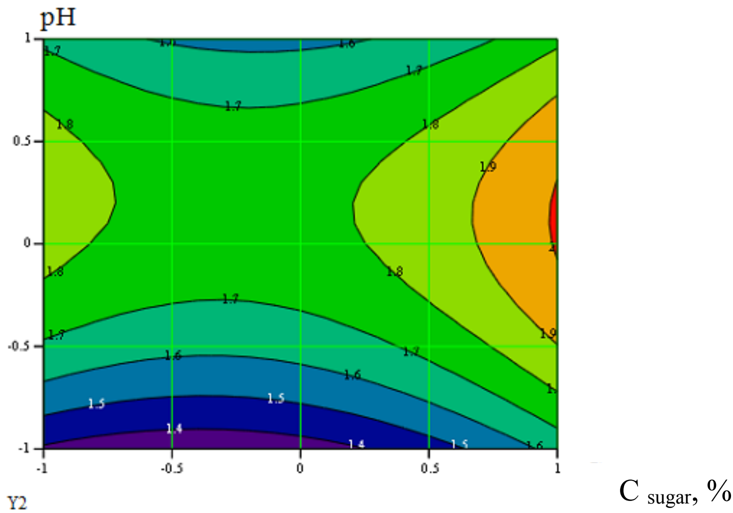


Figure 2.15. Maximum values of effective viscosity for model systems on the base of «Endura» starch

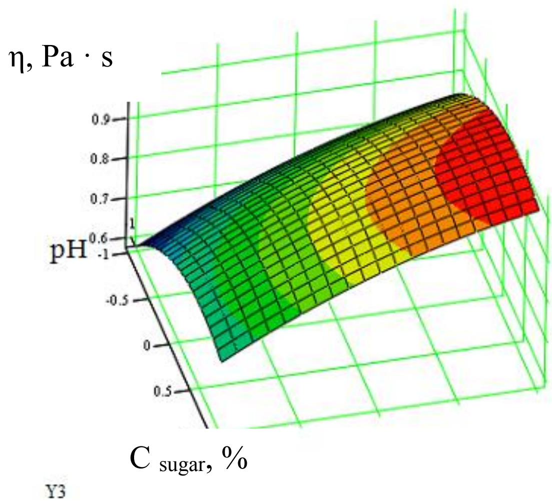


Figure 2.16. Mathematical model of response surface for model systems on the base of corn amylopectin starch

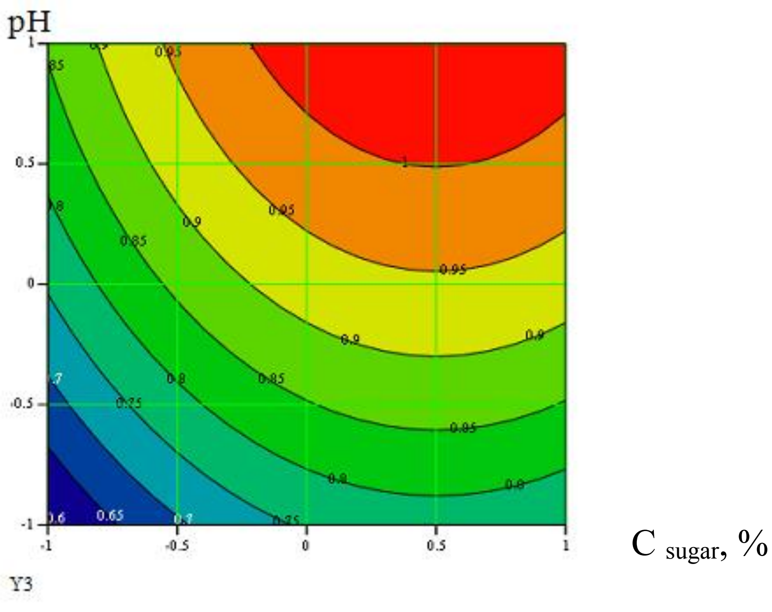


Figure 2.17. Maximum values of effective viscosity for model systems on the base of corn amylopectin starch

According to the optimization results, the model system «starch – citric acid –white sugar – water» has the following intervals of optimization parameters, namely the maximum effective viscosity. The maximum value of the effective viscosity of model systems on the base of wax corn starch «Prima» is up to 2,10 ± 0,06 Pa · s with pH value of 3,8 – 4,0 and white sugar content of 20,0 – 30,0%. During the optimization of model systems on the base of tapioca starch «Endura» it is determined that the maximum viscosity value is 2,30 ± 0,06 Pa · s with pH value of 4,0 – 5,0 and white sugar content of 25,0 – 30,0%. The maximum effective viscosity value of model systems on the base of amylopectin starch is 1,00 ± 0,03 Pa · s with pH value of 3,5 – 5,0 and white sugar content of 25,0 – 30,0%.

One of the main properties of pectic substances is the ability to viscosity increasing, which depends on the pectins' nature, temperature, concentration, presence of related substances – monosugars, organic acids, salts and others. For the study at the model level, apple highly esterified pectin at concentrations of 0,5 to 3,0% in the composition with the starch samples of 8% concentration is selected (fig. 2.18).

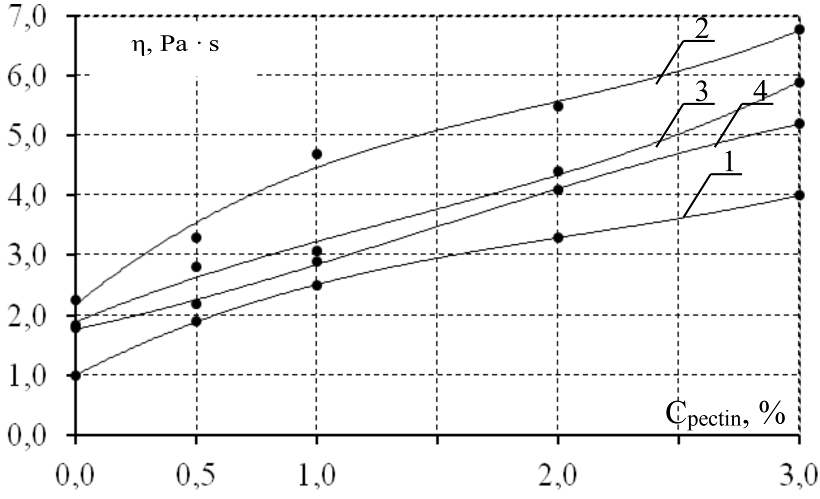


Figure 2.18. The GSD effective viscosity dependence on pectin concentration for starch-based GSD: 1 – corn amylopectin; 2 – wax corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca «Indulge» (under γ =50s^{-1})

It is experimentally proved that, with the increase of pectin concentration up to 3,0%, the viscosity of model systems increases in 2,0 – 2,5 times for all studied systems. Moreover, significant increase of viscosity values is observed at the pectin concentration in the system above 1,0%. This tendency is particular characteristic of GSD on the base of wax corn starch «Prima» (2), where the viscosity values increase from 4,5 ± 0,1 to 6,8 ± 0,2.

For comprehensive substantiation of the sweet sauces technology, we consider that it is expedient to study the multi-component model systems. The components' content is substantiated by diagnosis of sauces' composition on the base of fruit and berry raw material. The effective viscosity study data are presented in fig. 2.19.

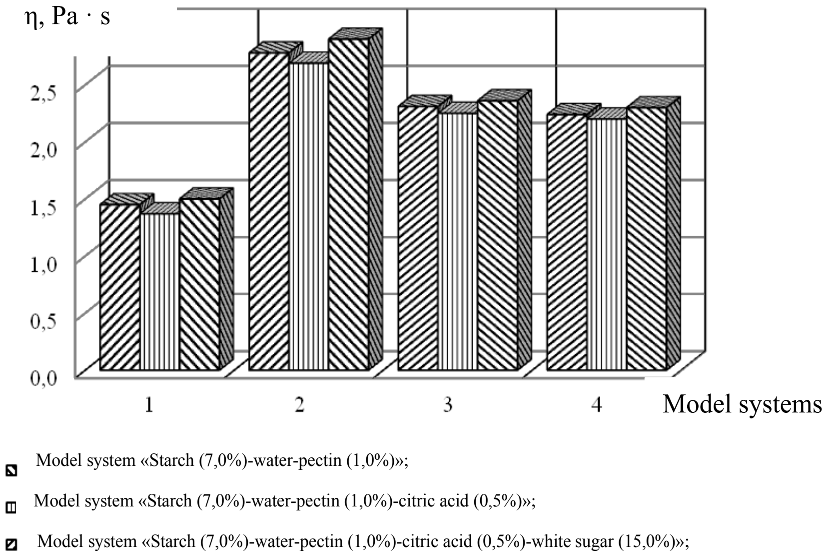


Figure 2.19. The MS effective viscosity dependence on starch concentration: 1 – corn amylopectin; 2 – wax corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca «Indulge» (under $\gamma = 50 s^{-1}$)

As it can be seen, the model systems components and their interaction with each other significantly affect on the viscosity. Model systems on the base of wax corn starch «Prima» with pectin content of 3,0 ± 0,1 Pa · s are characterized by the maximum viscosity values and model systems «water – starch – pectin – citric acid» on the base of corn amylopectin starch of 1,45 ± 0,1 Pa · s are characterized by the minimum viscosity values. The acid presence slightly reduces the viscosity of model systems. It is known that acids which are introduced into polysaccharide solutions reduce its viscosity better than low pH and polysaccharide concentrations. The study of the acid effect on the viscosity of all model systems «water – starch – pectin – citric acid» shows that the acid presence causes viscosity decreasing; it can be explained by the process of partial acid hydrolysis of pectin and starch molecules in solution, as well as by the macromolecules conformational state.

Heat treatment of model systems «water – starch – pectin – acid – sugar» causes slight viscosity increasing: viscosity of model systems on the base of corn amylopectin starch increases in 0,5 times; viscosity of model systems on the base of wax corn starch «Prima» – in 0,75 times; viscosity of model systems on the base of tapioca starch «Endura» – in 0,5 times; viscosity of model systems on the base of tapioca starch «Indulge» – in 0,5 times. Probably, the white sugar, which is added to the polysaccharide solutions after heat treatment, stabilizes the aggregates at the beginning of their formation and thus helps to increase their amount.

The relative concentration of the gelling agent increases, double molecular pectin helices form and energy effect of their supramolecular structure aggregation decreases because of white sugar dehydrating action.

The electrolyte ions which present in the sauces significantly affect on the structure, texture and organoleptic characteristics of the product.

Salts include cations of calcium, sodium, potassium and anions such as chlorine, carbonates and phosphates. Salts also include chelating agents, such as ethylenediaminetetraacetic acid (EDTA), which slows down the oxidative damage of the product. Sorbic and benzoic salts are also used as preservatives. Electrolyte ions interact with starch, provide the interaction between different molecules with spatial mesh structure formation. Salts reduce the solutions' freezing temperature and increase boiling temperature, as well as change the product's taste as a whole [132].

The salts' effect was determined according to effective viscosity values (fig. 2.20).

The calcium ions presence in the GSD composition slightly reduces the effective viscosity of all types of GSD. The viscosity reduction is about 10,0% for the corn amylopectin starch. More pronounced viscosity decreasing is observed for GSD on the base of «Prime», «Endura» and «Indulge» starches, which is 2,0 ± 0,06; 1,8 ± 0,05; 1,5 ± 0,04 Pa · s, respectively.

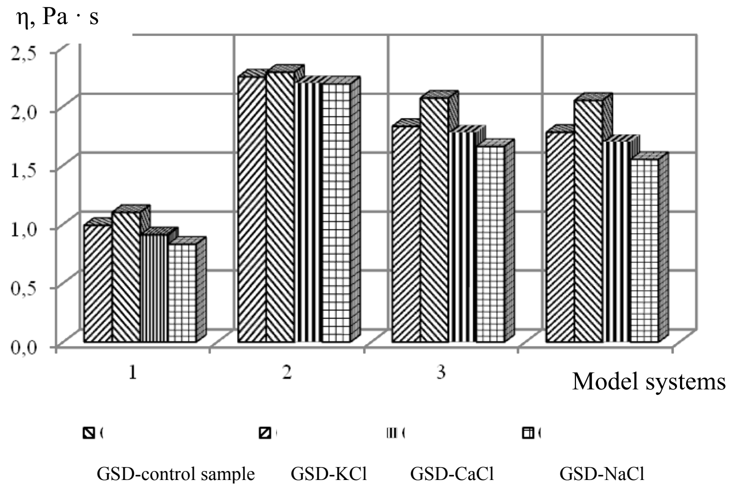


Figure 2.20. The effective viscosity dependence of starch-based with salts content GSD: 1 – corn amylopectin; 2 – wax corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca «Indulge» (under ɣ =50s^{-1})

Study of GSD gelatinization process under potassium chloride presence shows that under potassium chloride concentration of 0,1 n, GSD effective viscosity increases and it is 1,60 ± 0,04 Pa · s for GSD on the base of corn amylopectin starch, and for GSD on the base of «Prima» starch it is 2,33 ± 0,07 Pa · s, for GSD on the base of «Endura» starch it is 2,18 ± 0,6 Pa · s, for GSD on the base of «Indulge» starch it is 2,00 ± 0,06 Pa · s.

Sodium chloride has inhibitory effect on the viscosity of GSD on the base of corn amylopectin starch and it is 0,8 ± 0,02 Pa · s.

The sodium chloride presence in the system practically does not change the viscosity of GSD on the base of: «Prima» starch – 2,21 ± 0,06 Pa · s, «Endura» starch – 1,78 ± 0,05 Pa · s, «Indulge» starch – 1,91 ± 0,05 Pa · s; it proves their resistance to sodium chloride.

One of the main ways of culinary products long-term storage is its freezing, which helps to prevent the microbiological processes development and sharp decreasing of enzymatic and physical and chemical processes rate, increases the production organization efficiency.

According to experts data [133–135] about 85% of water is converted to ice during freezing. Cryoscopic temperature depends on the solution concentration, solutes association degree and solvent properties.

Since the sauces production concept involves their use in the low temperature range, we conduct the study of the GSD freezing-thawing effect at concentration of 8,0% on the effective viscosity (table 2.7). GSD were frozen at temperature of -20 ± 2°C for 15 days, after which the samples were thawed to temperature of 20 ± 2°C.

Table 2.7. **GSD experimental studies data in the «freeze-thaw» cycle**

Starch-based GSD	**Effective viscosity values (Pa · s) (under γ =50s^{-1}) under freezing duration, days**			
	Control sample T=14°C	**5**	**10**	**15**
Corn amylopectin	2,1±0,06	0,78±0,02	-*	-*
Wax corn «Prima»	3,8±0,1	3,7±0,1	2,8±0,08	2,7±0,08
Tapioca «Endura»	3,7±0,1	2,9±0,08	2,7±0,08	2,6±0,04
Tapioca «Indulge»	3,6±0,1	2,8±0,08	2,3±0,04	2,2±0,03
Note.* it wasn't studied because of system's heterogeneity				

According to the obtained data, not all GSD samples retain stability during «freezing-thawing» cycle. Thus, GSD on the base of corn amylopectin starch after 5-10 days of freezing and subsequent thawing showed heterogeneity of the system and lost their viscous and fluid properties.

Slight viscosity decreasing is observed during the fifth day of storage for GSD on the base of «Prima» starch, effective viscosity is 3,7 ± 0,1 Pa·s, it is 2,8 ± 0,08 Pa·s during the tenth day of storage and during the fifteenth day of storage the effective viscosity is 2,7 ± 0,08 Pa·s.

For the Endura, Indulge, Freezing-thawing process is accompanied by the small amount of the liquid phase releasing for GSD on the base of «Endura», «Indulge» starches. The viscosity of «Endura» starch-based GSD also decreases depending on the freezing process duration: 5 days – 2,9 ± 0,08 Pa·s, 10 days – 2,7 ± 0,08 Pa·s, 15 days – 2,6 ± 0,04 Pa·s. The viscosity of «Indulge» starch-based GSD is characterized by parameters' decreasing depending on the freezing process duration: 5 days – 2,8 ± 0,05 Pa·s, 10 days – 2,3 ± 0,04 Pa·s, 15 days – 2,2 ± 0,03 Pa·s. Organoleptic indices of GSD on the base of studied starches before freezing and after freezing-thawing processes after 5 days of storage were determined (table 2.8).

Table 2.8. **GSD organoleptic indices study data (C_s=7,0%) under the effect of freezing-thawing for 5 days**

Starch-based GSD	GSD appearance	
	before freezing	after freezing-thawing (τ=5days)
Corn amylopectin	Non-transparent gel of white color, medium thickness, without sediment	Gel with free moisture separation, exfoliation and aggregated sediment
Wax corn «Prima»	Homogeneous transparent gel, without sediment	Homogeneous transparent gel, without sediment
Tapioca «Endura»	Homogeneous transparent gel, medium thickness, without sediment	Homogeneous gel, with small amount of separated aqueous phase
Tapioca «Indulge»	Non-transparent gel with cream colour tint, medium thickness, without sediment	Non-transparent gel, with small amount of separated aqueous phase

One of the main research tasks is substantiation and development of technology, including long-term storage sweet sauces. The stability of physical and chemical, organoleptic, microbiological parameters or their minimal evolution is requirement for long-term storage food products.

GSD liquid phase state at concentration of 7,0% during their storage at temperature of 1...6°C and storage duration up to 90 days was studied for the advanced scientific and practical concept proving (fig. 2.21).

It is established that for GSD on the base of corn amylopectin starch, the liquid phase releasing occurs during the seventh day with moisture amount of 1,5 ± 0,1% and lasts for 8 days to 9,.0 ± 0,2%. Small amount of released liquid phase(3,0 – 4,0%) is identified during storage GSD on the base of «Endura», «Indulge» starches for 10 days. Liquid phase releasing does not occur for 90 days for GSD on the base of «Prima» starch; it proves system's stability.

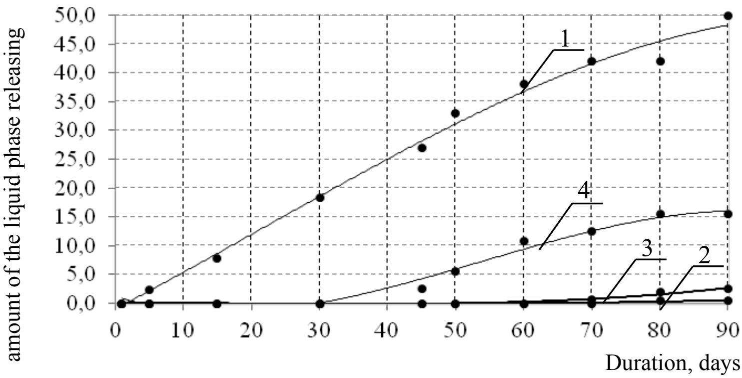


Figure 2.21. The dependence of the GSD on the base of starches stability on storage duration ($t_{storage}$=1…6°C) : 1 – corn amylopectin; 2 – wax corn «Prima»; 3 – tapioca «Endura»; 4 – tapioca «Indulge»

Study of physical modification starches properties, their changes under destructive factors effect, modeling of storage conditions, use and sale allows the substantiation of starch types and rational parameters of their use in the sweet sauces technology (table 2.9).

Table 2.9. **Rational parameters of GSD on the base of physical modification starches (PMS) obtaining**

Index	Measurement units	Rational parameters		
		dressings	toppings	fillings, dips
Type and content of starch				
Wax corn «Prima»	%	2,0–3,0	3,5–7,0	7,5–9,0
Tapioca «Endura»		2,0–3,5	4,0–7,5	8,0–9,0
Tapioca «Indulge»		3,0–4,0	4,5–8,0	8,5–9,0
Heat treatment temperature				
Wax corn «Prima»	°C	69° C ≤ t ≤ 99° C		
Tapioca «Endura»		68° C ≤ t ≤ 99° C		
Tapioca «Indulge»		72° C ≤ t ≤ 99° C		
System's pH for starch-based GSD				
Wax corn «Prima»	pH units	pH≥ 3,0		
Tapioca «Endura»		pH≥ 3,0		pH≥ 4,0
Tapioca «Indulge»		pH≥ 3,0	pH≥ 3,5	pH≥ 4,5
White sugar content for starch-based GSD				
Wax corn «Prima»	%	5–10	15–20	25–40
Tapioca «Endura»			15–30	35–40
Tapioca «Indulge»				

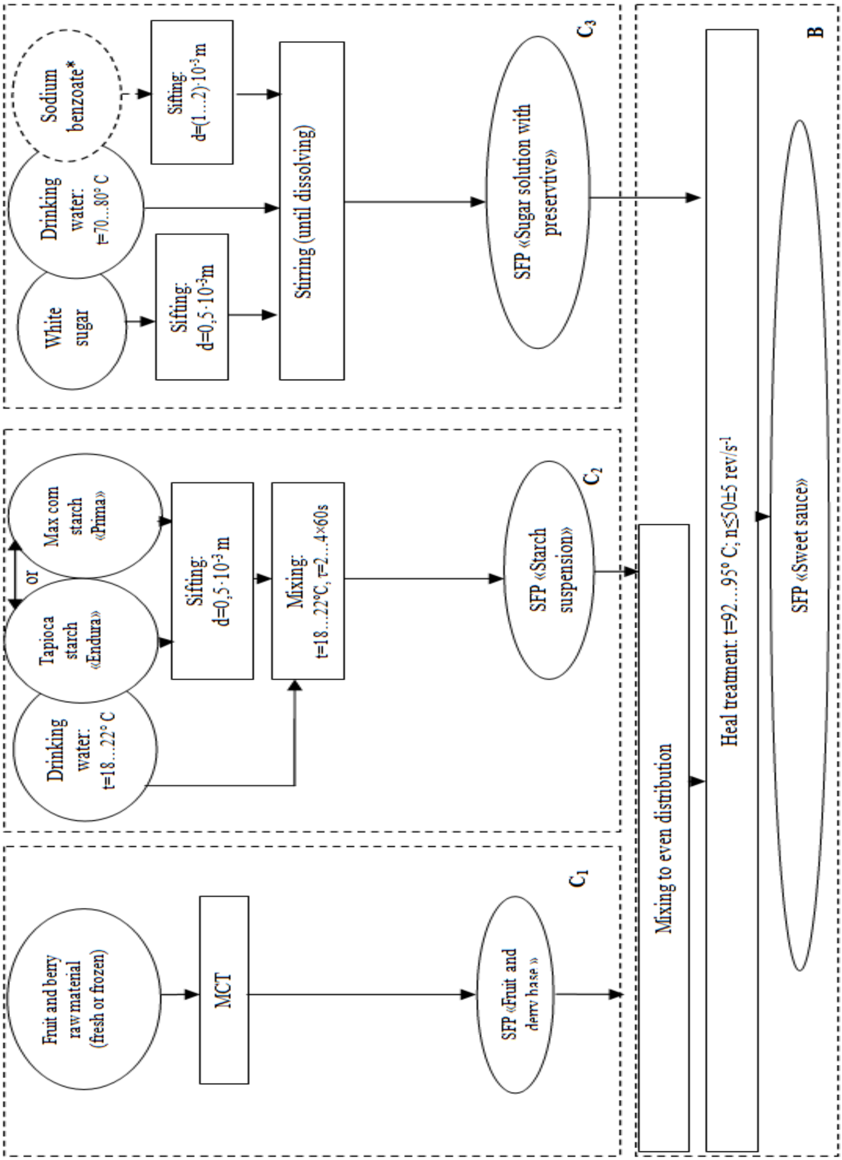
It is established the expediency of «Prima», «Endura» physical modification starches use on the base of properties study of different brands starches. The rational conditions of GSD obtaining, in particular, the starch content for the sauce consistency respective types, system pH and white sugar content were determined. It is proved that GSD on the base of «Indulge» starch don't meet technological requirements for the most types of sauces because of inappropriate organoleptic parameters (turbidity, opacity).

Under sweet sauces recipes developing, it is necessary to take into account information about the ways of certain type textures forming. Consumers tend to compare the organoleptic characteristics of new products with traditional ones, so it is possible to predict in advance which texture will be required.

The technological system model of semi-finished sweet sauces is presented as complete system (fig. 2.22), within which separate subsystems are marked out – C_1, C_2, C_3, B; these subsystems operation is aimed at the initial result obtaining of system functioning – sweet sauces formation with use of «Prima», «Endura» starches.

The C_1 subsystem presupposes fruit and berry base. Experimental studies establish that the system consistency regulation process depends primarily on the type and content of starch, pH value, sugar concentration and temperature. Within the C_2 subsystem functioning white sugar dissolving in the recipe water quantity at temperature of 70…80°C occurs. Within the C_3 subsystem, the semi-finished product «Starch suspension» is obtained by mixing certain starch amount in water and short-term holding for swelling. It is determined that the starch content should be in the range of 2,0 – 9,0% for required viscosity and structure properties providing.

The subsystem B functioning involves the preparation of semi-finished sweet sauce on the base of fruit and berry raw material with specified physical and chemical and organoleptic characteristics, which are stable during storage.



Note.* for semi-finished long-term storage sweet sauces

Figure 2.22. Production technological system of semi-finished sweet sauce

PART 3
SCIENTIFIC SUBSTANTIATION AND DEVELOPMENT OF SWEET SAUCES TECHNOLOGY

3.1. Study of the recipe components effect on physical and chemical and structural and mechanical properties of model fruit and berry systems

Study results (part 2) allow substantiation of starches types, ways of GSD obtaining with corresponding structural and technical characteristics and determination of model systems properties changes under the technological factors effect. The expediency of wax corn «Prima» and tapioca «Endura» starches use is proved; these starches can form stable GSD, as well as under destabilizing factors effect (presence of acids, sugars, heat treatment, mechanical action, freezing, etc.).

Recipe composition substantiation is preceded by the study of industrial production prototype products, which are ranked by purpose (dressings, toppings, dip and fillings) and reference characteristics determination (fig. 3.1, table 3.1).

The technology of sauces on the base of fruit and berry raw material involves:

– the use of fruit and berry raw material in amount which provides the formation of organoleptic characteristics by realizing the properties of natural raw material, appropriate flavors because of flavoring and coloring natural substances;

– use of wax corn «Prima», tapioca «Endura» starches for thickening and stabilizing the sauces consistency, toppings during storage and production processes, realization in the composition of finished products;

– formation of specified consumer and technological properties of semi-finished products.

The above mentioned requires studies which are aimed at the substantiation:

– type, content and sequence of fruit and berry raw material introduction into the recipe mixture;

– study of physical and chemical and technological properties of model systems for the production of semi-finished sweet sauces;

– recipe composition and technological process of semi-finished sweet sauces production.

The technological principles of sweet sauces obtaining with use of physical modification starches are determined by the specificity of functional and technological properties which are associated with the product viscosity, fluidity effect, texture («long», «short»), as well as colloidal stability under conditions of storage, temperature changes (heating , reheating, freezing).

The product's ideology involves, first of all, the use of natural raw material of vegetable origin (fruits, berries) and concentrates on their base. The substantiation of fruit and berry raw material choice is based primarily on the consumer preferences study.

Juices concentrates and fruit and berry puree were used during the studies. Chemical composition and physical and chemical parameters of the model systems were studied for substantiation the content of fruit and berry raw material in their composition (table 3.2 – 3.4).

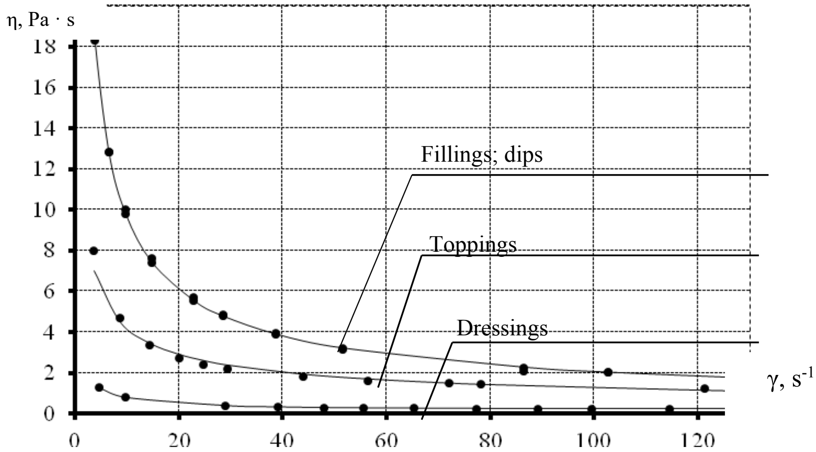


Figure 3.1. The dependence of effective viscosity on the shear rate of industrial production sauces on the base of fruit and berry raw material

Table 3.1. **Reference indices characteristics of industrial production sweet sauces**

Index	**Sauces indices characteristics**				
Sweet sauces groups	**Dressings**	**Toppings**		**Dips**	**Fillings**
Consistence	liquid	medium thickness		thick	
Sauces homo-geneity	homo-geneous	homo-geneous	hetero-geneous	homo-geneous	hetero-geneous
Effective viscosity (Pa · s) (γ=50 s^{-1})	0,30±0,01	1,50±0,04	2,07±0,1	3,07±0,1	3,50±0,1
Texture indices at rest state	viscous and tenuous	viscous and fluid	viscous and fluid, elastic	viscous and elastic	gel-like, elastic
Fluidity characteristic	fluid «long» texture			the texture can hold on a horizontal surface, «short»	

Table 3.2. **Chemical composition of fruit and berry puree [136; 137]**

Index	**Measurement unit**	**Indices for purée**								
		cranberry	**blueberry**	**black currant**	**cherry**	**strawberry**	**raspberry**	**apple**	**orange**	**banana**
Protein mass fraction	%	0,5	1,1	1,0	0,8	0,8	0,8	0,4	0,9	1,5
Carbohydrates mass fraction, including	%									
– glucose		2,5	2,1	1,5	5,5	3,7	3,9	2,0	2,4	5,5
– fructose		1,1	4,0	4,2	4,5	3,8	3,9	5,5	2,2	5,0
– sucrose		0,2	0,7	1,0	0,3	0,6	0,5	1,5	3,5	3,7
– fiber		2,0	4,5	3,0	0,5	5,5	5,1	0,6	1,4	1,1
– starch		-	0,4	0,6	–	0,1	–	0,8	–	2,0
– pectin		0,7	1,0	1,1	0,4	0,7	0,6	1,0	0,6	0,4
Organic acids mass fraction, including	%									
– tartaric		–	0,1	–	–	–	–	0,1	–	–
– citric		1,1	1,7	2,0	0,1	0,03	0,04	0,08	1,0	0,09
– oxalic		0,02	0,03	0,06	0,02	0,01	0,01	0,01	–	–
– malic		1,0	1,0	0,25	1,2	1,1	1,0	0,7	–	1,3

Table 3.3. **Physical and chemical indices of fruit and berry puree**

Index	**Measurement unit**	**Indices for fresh raw material purée**							
		cranberry	**blueberry**	**black currant**	**cherry**	**strawberry**	**raspberry**	**apple**	**banana**
1	2	3	4	5	6	7	8	9	10
Mass fraction of solids	%	12,8±0,3	13,7±0,4	10,0±0,3	12,0±0,3	8,5±0,2	9,4±0,2	15,8±0,5	24,2±0,7
Active acidity (t=20±2°C)	pH units	3,07±0,09	3,13±0,09	2,86±0,07	3,33±0,09	3,34±0,09	3,21±0,09	3,60±0,10	4,81±0,10

Continuation of table 3.3.

1	2	3	4	5	6	7	8	9	10
Titratable acidity	% in recalculation to citric acid (monohydrate)	2,14±0,06	3,01±0,09	2,30±0,06	–	–	–	–	–
	% in recalculation to malic acid	–	–	–	1,83±0,05	1,78±0,05	1,25±0,03	1,30±0,03	1,10±0,03
Effective viscosity (t=20±1°C, γ=50 s^{-1})	Pa·s	0,50±0,01	0,61±0,01	0,59±0,01	0,53±0,01	0,49±0,01	0,50±0,01	0,46±0,01	0,88±0,02

Table 3.4. **Physical and chemical indices of concentrated juices**

Index	**Measurement unit**	**Indices for concentrated juices**				
		cherry	**raspberry**	**strawberry**	**peach**	**orange**
Mass fraction of solids	%	65,0±1,9	63,0±1,8	65,0±1,9	67,0±2,0	62,0±1,8
Active acidity (t=20±2°C)	pH units	3,35±0,1	3,11±0,09	3,17±0,09	3,65±0,1	3,44±0,1
Titratable acidity	% in recalculation to citric acid	–	–	–	1,38±0,04	1,33±0,04
	% in recalculation to malic acid	2,78±0,08	2,83±0,08	2,51±0,07	–	–
Effective viscosity (t=20±1°C, γ=50 s^{-1})	Pa·s	0,45±0,01	0,35±0,01	0,41±0,01	0,39±0,01	0,40±0,01

It is determined that juice concentrates have more solids (62,0 – 67,0%) than fruit and berry puree (8,5 – 24,2%). The active acidity of the fruit and berry raw material (2,86 – 3,55), organic acids content, pectic substances presence can affect on structural and mechanical characteristics of the sauce.

At the model systems level, we studied the effect of acids on the GSD properties, determined the relationship between pH values and structural and mechanical properties and identified the acids' hydrolytic action degree.

Model systems «puree – water – starch» viscosity studies data (fig. 3.2, 3.3) prove starches behavior in model systems – effective viscosity increases under starch content increasing.

Rational concentrations of physical modification starches «Prima» for dressings are 1,5 – 2,0%, for toppings they are from 2,0 to 6,0% – respectively for all puree types. The starch content in the range of 6,3 – 7,5% under puree presence provides the formation of thick dense texture, which characterizes dips and fillings.

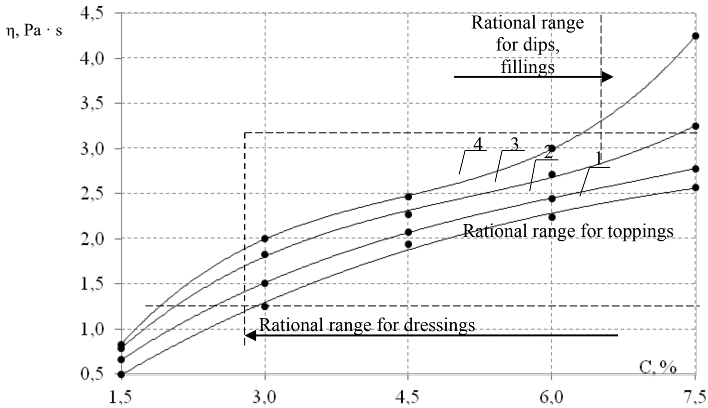


Figure 3.2. Dependence of puree-based MS («purée – water – PMS "Prima"») effective viscosity on starch content: 1 – cranberry; 2 – black currant; 3 – raspberry; 4 – banana (γ=50 s^{-1})

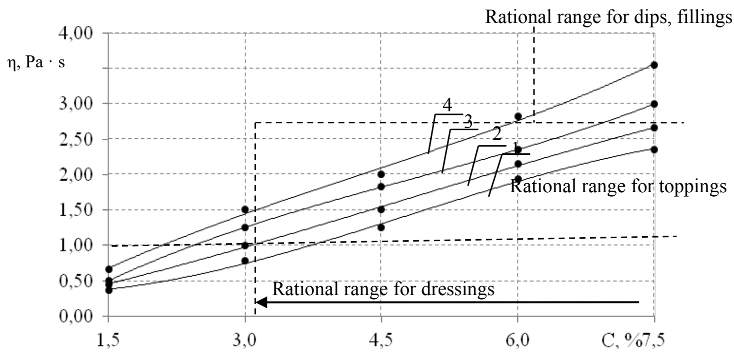


Figure 3.3. Dependence of puree-based MS («purée – water – PMS "Endura"») effective viscosity on starch content: 1 – cranberry; 2 – black currant; 3 – raspberry; 4 – banana γ=50 s^{-1})

Model systems on the base of «Endura» starch show analogous tendencies, but at different concentrations. Model systems on the base of «Endura» starch have different textural characteristics, which allows sauces structure regulation:

– for dressings (have liquid consistency, spread quickly on a horizontal surface) it is advisable to use model systems on the base of cranberry and black currant puree with starch content of 1,5 – 3,0%, model systems on the base of raspberry and banana puree with starch content of 1,5 – 2,5 %;

– for toppings the required starch content is from 3,0 to 5,5% (for model systems on the base of raspberry and banana puree);

– for toppings, dips which have thick consistency with «short» texture, the starch content is about 7,0% for model systems on the base of all puree types (except banana puree, which forms gel-like system).

Sauce technologies can use concentrated juices (CJ): cherry, raspberry, peach, which have a number of advantages for both consumer and producer. Therefore, we further study model systems «concentrated juices – water – starch» (fig. 3.4, 3.5).

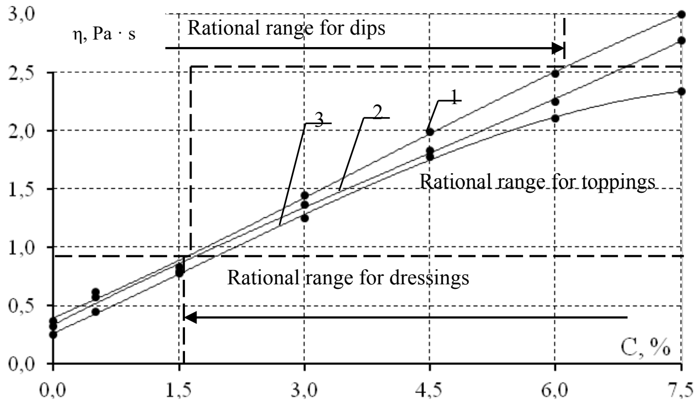


Figure 3.4. Dependence of concentrated juice-based MS «Juice – water – PMS “Prima”» effective viscosity on starch content: 1 – cherry; 2 – raspberry; 3 – peach (γ=50s^{-1})

From the above data it can be seen that all model systems are characterized by the general character of viscosity increasing, under starch content increasing. The analysis of the curves allows statement that use of «Prima» starch in amount of 0,5 – 1,5% is the most rational for dressings viscosity characteristics forming.

The rational range for toppings formation is substantiated on the base of studies MS viscosity at «Prima» starch content of 1,5 – 6,0% excepting concentrated peach juice-based model system (up to 7,5%). It is established that starch content of 6,0 – 7,5% is rational for dip-sauces or toppings preparation.

«Endura» starch model systems are only recommended for dressings and toppings. So, model system consistency at starch content of 1,5 – 2,5% is liquid and rather fluid, and under concentration increasing to 7,5% it turns into viscous and fluid.

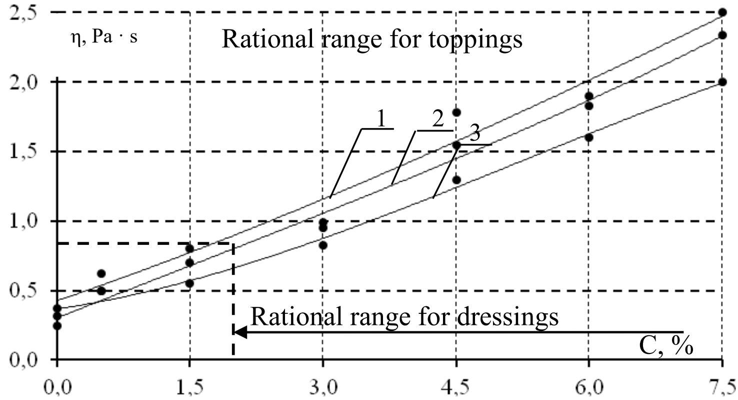


Figure 3.5. Dependence of concentrated juice-based MS «Juice – water – PMS "Endura"» effective viscosity on starch content: 1 – cherry; 2 – raspberry; 3 – peach (γ=50s^{-1})

It is determined (part 2) that during cooling, GSD on the base of «Prima» starch, to temperature of 1…6°C the viscosity increases because of hydrogen bonds formation and GSD on the base of «Endura» starch are characterized by slight increasing of the viscosity indices during cooling. Therefore, we propose using «Endura» starch for more liquid systems which have homogeneous texture (for example, dressings, homogeneous toppings, without fillers).

It is known that sauces' consistency can be created by two mechanisms: solids concentrating (for example, boiling) or structure-forming agents introducing. Because of the parameter «duration» is variable in the technological scheme and it is chosen depending on the amount of mixture which is simultaneously processed, equipment type.

The next level of research involves the maximum approximation of the model system composition to the recipe composition of sweet sauces. Therefore, we developed composition of model systems with different sugar content and studied model systems effective viscosity on the base of previous studies (fig. 3.6). In addition to sweet taste forming, sugar has significant effect on the consistency by solids content increasing.

It is found that sugar introduction in concentrations up to 10,0% does not significantly affect on the model systems viscosity. The optimal sugar content for model system (1) is 15,0%. The sugar concentration for model system (2) varies in the range of 15 – 20%.

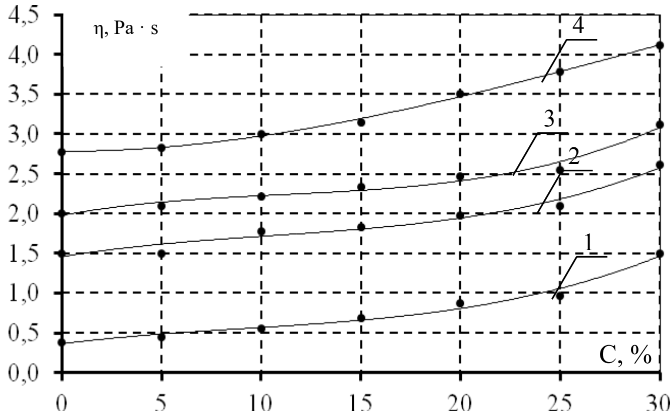


Figure 3.6. The effective viscosity dependence on the composition of model system on the base of: 1 – peach concentrated juice; 2 – cherry concentrated juice; 3 – raspberry puree; 4 – black currant puree (γ=50s^{-1})

Systems viscosity increases because of starch crystallization under sugar content increasing. According to organoleptic indices toppings with homogeneous structure under sugar concentration increasing change color and taste.

The model system (3) at sugar concentration of more than 15% forms viscous and fluid elastic systems. If the sugar concentration increases to 20,0%, the viscosity is 2,47 ± 0,07 Pas · s; these indices are rational for the formation of toppings with fillers.

Rational range of sugar concentration for dips and fillings was determined. It is established that at concentration of 20% the model system (4) has viscous and thick consistency, which is characterized by the dip-sauces consistency. It is studied that further sugar concentration increasing from 25 to 30% causes gel-like elastic consistency formation, which viscosity varies from 3,78 ± 0,1 to 4,12 ± 0,1Pa · s.

The recipe composition and technological process of production must provide the formation of the specified consumer properties and their stability during the shelf life. The starch «aging» phenomenon is significant drawback and it is accompanied by delamination, juiciness loss.

Model systems were studied at different concentrations of starches, according to their types – dressings, toppings, dips (table 3.5).

However, moisture exfoliation up to 8,0% is observed in model systems with corn starch content of 2,0% after 3 days of storage and at concentration of 7,5% moisture exfoliation occurs up to 18,0% during the 27th day.

The presented data prove the high functionality of «Prima», «Endura» starches including the processes of finished products storage.

Table 3.5. **Study of the model systems stability depending on the storage duration**

MS name and composition, %	The amount of released liquid phase, %	Storage duration before liquid exfoliation, days	Sauce appearance and consistency	
			MS with use of corn starch (control sample)	MS with use of physical modification starches
MS 1 (dressings) Peach concentrated juice – 27,0 Drinking water – 56,0 White sugar – 15,0 Corn starch (control sample) – 2,0 / «Endura» starch – 2,0	5,0/0,0	27/90	Consistency heterogeneity because of moisture exfoliation	Without changes
MS 2 (homogeneous topping) Cherry concentrated juice – 27,5 Drinking water – 54,0 White sugar – 15,0 Corn starch (control sample) – 3,5 / «Endura» starch – 3,5	8,0/0,0	3/90	Consistency heterogeneity because of moisture exfoliation	Without changes
MS 3 (topping with filling) Raspberry puree – 58,0 Drinking water – 22,0 White sugar – 15,0 Corn starch (control sample) – 3,5 / «Prima» starch – 3,5	12,0/0,0	5/90	Consistency is heterogeneous, with lumps formation. Film is formed on the surface. Moisture and system exfoliation occurs during MS mixing	Without changes
MS 4 (filling, dip) Black currant puree – 50,0 Drinking water – 22,5 Drinking water – 20,0 Corn starch (control sample) – 7,5 / «Prima» starch – 7,5	18,0/0,0	7/60	Consistency is heterogeneous with moisture exfoliation, dense, pudgy, with film on the surface	Without changes

During the scientific and practical concept development (subsection 2.1) we provide the possibility of sauces use in frozen products composition or in the freezing – thawing cycle.

At the previous stages we studied the effect of low temperatures on the GSD properties and determined the high potential of «Prima», «Endura» starches for functional properties providing. But MS recipe composition «loading» with food ingredients (fruit and berry raw material, sugar) needs to be checked during «freezing – thawing» cycle (table 3.6). The control sample is model system on the base of corn starch.

The study results identify instability of MS on the base of corn starch during «freezing − thawing» cycle. MS on the base of «Endura», «Prima» starches are resistant to low temperatures, which is proved by the effective viscosity values before and after thawing, which are almost unchangeable.

Thus, the conducted researches complex scientifically substantiates and proves the expediency of «Prima», «Endura» starches use for sweet sauces, which make it possible to create variable consistencies are time-stable and resistant to destabilizing factors action.

Table 3.6. **MS effective viscosity values under freezing – thawing process effect**

Model system	MS viscosity, Pa ·s (γ=50s^{-1}) on the base of starches:					
	before freezing (t=20±2°C)			after thawing (t=20±2°C; τ=7 days)		
	corn	tapioca «Endura»	wax corn «Prima»	corn	tapioca «Endura»	wax corn «Prima»
MS 1 on the base of peach concentrated juice (dressing)	1,10±0,03	1,60±0,04	–	-*	1,40±0,04	–
MS 2 on the base of cherry concentrated juice (homogeneous topping)	2,5±0,1	3,0±0,1	–	-*	2,8±0,1	–
MS 3 on the base of raspberry puree (heterogeneous topping)	3,3±0,1	–	3,8±0,1	-*	–	3,7±0,1
MS 4 on the base of black currant puree (filling, dip)	3,9±0,1	–	4,4±0,1	-*	–	4,4±0,1
Note.* It wasn't studied because of systems' heterogeneity						

3.2. Development of recipe composition and production technological scheme of sweet sauces on the base of fruit and berry raw material

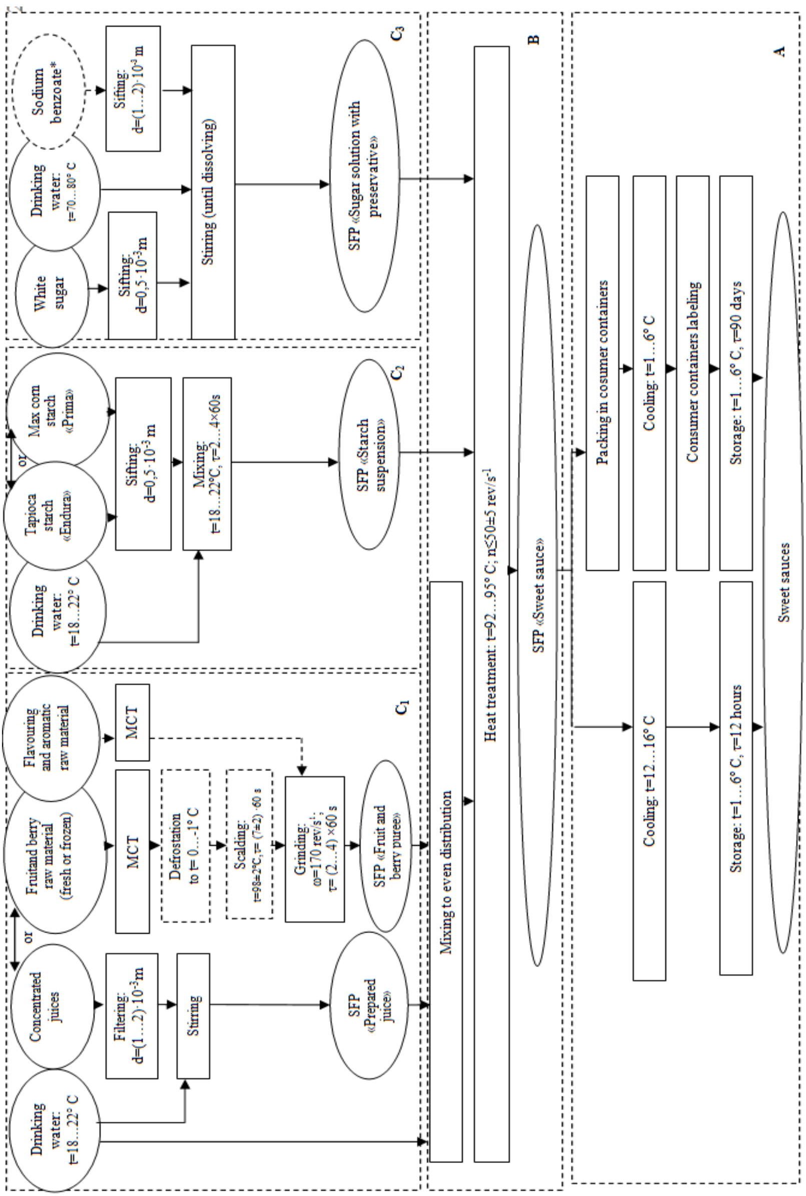
We developed recipe composition and sauces range on the base of conducted experimental researches (table 3.7). The production technological scheme of sweet sauces on the base of fruit and berry raw material is presented in fig. 3.7. The technological system functioning is provided by the functioning of its individual components in accordance with the objective (table 3.12).

Table 3.7. **The recipe composition of sweet sauces on the base of fruit and berry raw material**

The recipe component	**Raw material inputs for sauces, %**									
	dressing «Peach»		**topping «Cherry»**		**topping «Berry mix»**		**dip «Strawberry and banana»**		**filling «Currants»**	
	gross weight	**net weight**	**gross weight**	**net weight**	**gross weight**	**net weight**	**gross weight**	**net weight**	**gross weight**	**net weight**
1	2	3	4	5	6	7	8	9	10	11
Fresh bananas	-	-	-	-	-	-	20,6	15,7	-	-
Fresh or frozen strawberry	-	-	-	-	-	-	42,0	41,5	-	-
Semi-finished «Strawberry and banana puree»	-	-	-	-	-	-	-	*55,0*	-	-
Fresh or frozen black currant for puree	-	-	-	-	-	-	-	-	42,0	41,3
Fresh or frozen black currant	-	-	-	-	-	-	-	-	8,3	7,8

Continuation of table 3.7.

1	2	3	4	5	6	7	8	9	10	11
Semi-finished «Black currant puree with whole berries»	-	-	-	-	-	-	-	-	-	*47,0*
Frozen cherry without stone	-	-	-	-	16,9	15,7	-	-	-	-
Fresh or frozen raspberry	-	-	-	-	22,9	21,8	-	-	-	-
Fresh or frozen red currant	-	-	-	-	10,1	10,0	-	-	-	-
Concentrated strawberry juice	-	-	-	-	12,0	12,0	-	-	-	-
Semi-finished «Puree with whole berries»	-	-	-	-	-	*59,0*	-	-	-	-
Concentrated peach juice	30,0	30,0	-	-	-	-	-	-	-	-
Concentrated cherry juice	-	-	39,0	39,0	-	-	-	-	-	-
Drinking water	61,0	61,0	53,0	53,0	32,0	32,0	30,0	30,0	37,0	37,0
White sugar	17,0	17,0	17,0	17,0	18,0	18,0	23,0	23,0	24,0	24,0
Tapioca starch «Endura»	2,3	2,3	3,9	3,9	-	-	-	-	-	-
Wax corn starch «Prime»	-	-	-	-	5,7	5,7	8,4	8,4	8,7	8,7
Sodium benzoate *	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001
Raw material set weight	–	111,3	-	119,0	-	115,8	-	116,4	-	116,7
Output	**–**	**100,0**	**-**	**100,0**	**-**	**100,0**	**-**	**100,0**	**-**	**100,0**
Note.* for long-term storage sauces										



Note.* it is used in the composition of long-term storage sauces

Figure 3.7. Production technological scheme of sauces on the base of fruit and berry raw material

Table 3.8. **Technological system structure and purpose of components' functioning**

Subsystem	Subsystem's name	Subsystem operation purpose
A	Formation of sauce	Food product obtaining with specified properties and composition, which is ready for sale and consumption
B	Formation of semi-finished sweet sauces	Stabilization of sauce, filling by starch gelatinization in fruit and berry basis
C_1	Formation of semi-finished products «Fruit and berry puree» «Prepared juice»	Obtaining of puree and juice with specified technological properties
C_2	Formation of semi-finished product «Starch suspension»	Obtaining suspension which can thicken and stabilize the sauce system during heat treatment
C_3	Preparation of semi-finished product «Sugar solution»	Recipe components sifting for extraneous mechanical impurities removing and agglomerated particles destruction

At the next stage, we conduct standardization and research of developed products quality and safety indices.

3.3. Study of the sweet sauces quality and safety main indices

Sweet sauces with use of physical modification starches «Endura», «Prima», which are represented by dressings, toppings, dips and fillings are new food products on the Ukrainian food market. They can be consumed directly or as semi-finished products in other food products content.

We developed the sensory scale of sauces' assessment for organoleptic parameters standardization; it is decomposed by components and weight factors are determined (table 3.9).

Consistency indices (fluidity, thickness, base taste) are the most significant for organoleptic parameters formation, which significantly affect on the overall product sensing. Generalization of research results allows determination and standardization of the developed sauces organoleptic parameters (table 3.10). Sauces' assessment criteria are their colloidal stability, effective viscosity and organoleptic properties under heat and cyclic (re)heat treatment, during freezing-thawing process, storage.

On the base of previous experimental researches it is established that the pH value effects on the sauces' colloidal stability indices. Two assortment units are sampled for the study: homogeneous topping «Berry mix» with viscous and fluid consistency, pH value of (3,83±0,1), and filling «Currant» with thick consistency, pH value of (3,78±0,1). The pH values of other sauces' assortment units are close to these values.

It is established that reheat treatment of sweet sauces at temperatures above 100°C causes sauces' colloidal stability decreasing with different intensity and depends on the type and concentration of starch, which in turn is determined by the pH value of the sauce. Sauces' effective viscosity change is more intensive under reheat treatment, which determines their consistency indices (fig. 3.8).

Table 3.9. **The sensory analysis of sweet sauces on the base of fruit and berry raw material results**

Index	Index weighting factor	Weighting factor characteristics	Characteristic	Score							
				Dressings (a)		Homo-geneous toppings (b)		Hetero-geneous toppings (c)		Filling (d)	
				Syrup[1] (control sample)	Peach dressing	Cherry sauce[2] (control sample)	Topping «Cherry»	Raspberry sauce[2] (control sample)	Topping «Berry mix»	Fruit filling[4] (control sample)	Strawberry and banana filling
1	2	3	4	5	6	7	8	9	10	11	12
Appearance	0,2	0,83	Homogeneity	4,8	5,0	4,8	4,9	4,4	4,9	4,3	5,0
		0,17	Absence of extraneous particles	5,0	5,0	4,3	4,8	-	-	4,2	4,9
		0,17	Presence of fillers (particles)	-	-	-	-	4,7	4,9	-	-
Total score by the index				0,98	1,00	0,91	0,97	0,91	0,99	0,85	1,00
Consistency	0,25	0,4	«Long» fluidity	4,2	5,0	4,8	5,0	3,9	4,9	-	-
			«Short» fluidity	-	-	-	-	-	-	4,7	5,0
		0,3	Thickness	4,4	4,9	4,7	4,9	4,4	5,0	4,5	4,9
		0,3	Base taste	4,3	5,0	4,2	5,0	4,7	5,0	4,4	5,0
Total score by the index				1,08	1,24	1,14	1,24	1,08	1,24	1,13	1,20
Color	0,2	0,3	Homogeneity	4,7	5,0	5,0	5,0	4,8	4,9	4,8	5,0
		0,2	Distinctiveness	4,6	4,7	4,7	4,9	4,5	5,0	4,8	5,0
		0,2	Intensity	4,7	5,0	4,9	4,9	5,0	4,9	4,5	5,0
		0,3	Naturalness	5,0	5,0	4,9	4,9	4,8	5,0	4,8	4,8

Continuation of the table 3.9.

1	2	3	4	5	6	7	8	9	10	11	12
Total score by the index				0,95	0,99	0,98	0,99	0,95	0,99	0,94	0,98
Taste	0,15	0,1	Distinc-tiveness	4,9	4,9	4,7	5,0	4,1	4,9	4,5	5,0
		0,2	Balance	4,7	5,0	4,5	4,9	4,8	4,9	4,4	4,9
		0,1	Releasing rate	4,9	5,0	4,3	4,7	4,0	4,5	3,7	4,7
		0,3	Purity	4,7	4,9	5,0	5,0	3,7	4,8	3,9	4,8
		0,3	Naturalness	4,9	5,0	5,0	5,0	4,8	5,0	4,8	5,0
Total score by the index				0,72	0,74	0,71	0,74	0,64	0,72	0,64	0,72
Smell	0,2	0,3	Distinctiveness	4,5	4,9	4,4	5,0	4,5	4,9	3,9	4,9
		0,2	Compliance with the type of raw material used	3,5	4,7	4,9	5,0	4,7	4,9	5,0	5,0
		0,2	Stability	5,0	5,0	4,1	4,8	5,0	5,0	4,3	4,8
		0,3	Purity	4,8	5,0	4,9	4,9	4,1	5,0	4,7	5,0
Total score by the index				0,88	0,98	0,92	0,99	0,92	0,99	0,89	0,99
Overall score				4,64	4,95	4,64	4,88	4,48	4,88	4,40	4,86

Notes:

[1] – control sample (Syrup «Peach» TM «Delicia») [138]

[2] – control sample (Cherry sauce № 837) according to the recipes collection of dishes and culinary products [139]

[3] – control sample is changed because of filler introduction (Raspberry sauce № 837) according to the recipes collection of dishes and culinary products [139]

[4] – control sample (Fruit filling № 71) according to the recipes collection of flour confectionery and bakery products [140]

Table 3.10. **Quality organoleptic indices of sweet sauces on the base of fruit and berry raw material**

Sauce	Index		
	appearance and consistency	**color**	**smell and taste**
Dressing «Peach»	Homogeneous, uniformly liquid mass which spreads rapidly on a horizontal surface	Homogeneous in volume, corresponds to the peach color	Sweet and sour, with pronounced peach taste, without extraneous smell or taste
Topping «Cherry»	Homogeneous, uniformly rubbed puree-like mass, which slowly spreads on a horizontal surface	Homogeneous in volume, corresponds to the cherry color	Sweet and sour, with pronounced cherry taste, without extraneous smell or taste
Topping «Berry mix»	Homogeneous, uniformly rubbed puree-like mass, which slowly spreads on a horizontal surface with particles of red currant whole berries	Homogeneous in volume, corresponds to the berry color	Sweet and sour, with pronounced berry taste, without extraneous smell or taste
Filling «Currants»	Homogeneous, uniformly rubbed mass, which doesn't spread on a horizontal surface with particles of currant whole berries	Homogeneous in volume, from crimson to dark crimson color	Sweet and sour, with pronounced black currant taste, without extraneous smell or taste
Dip «Strawberry and banana»	Homogeneous, uniformly rubbed mass, which doesn't spread on a horizontal surface	Homogeneous in volume, from light pink to pink color	Sweet and sour, with pronounced strawberry and banana taste, without extraneous smell or taste

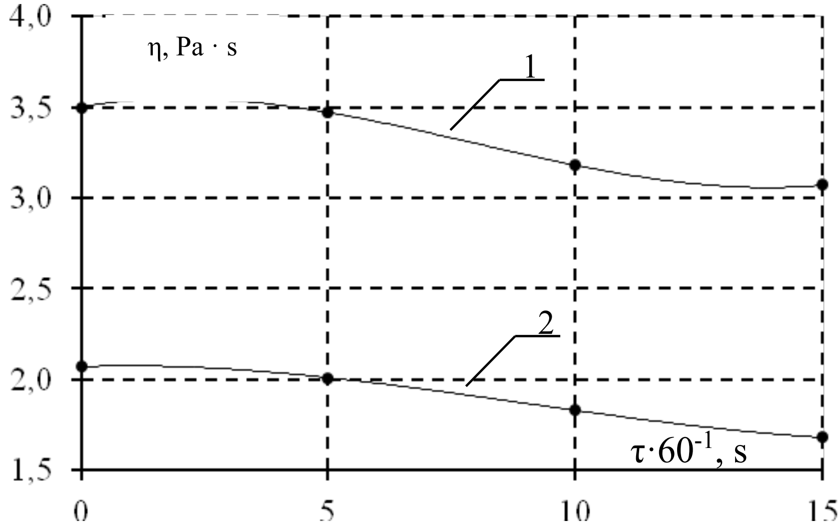
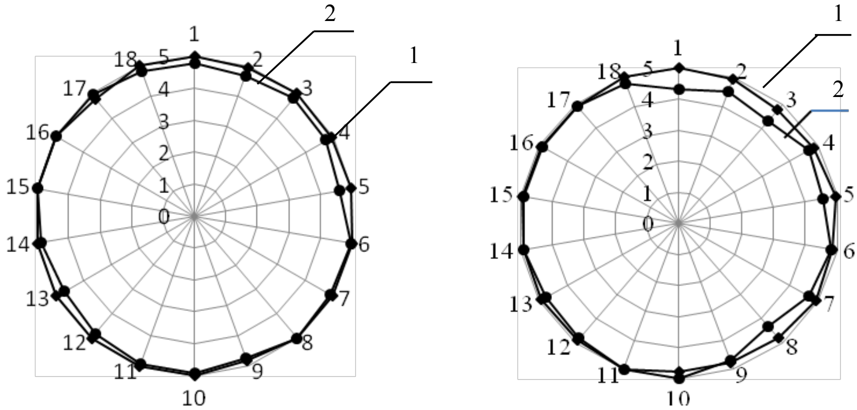


Figure 3.8. Dependence of the sauces' effective viscosity on the reheating duration: 1 – topping «Berry mix»; 2 – filling «Currants» (γ=50s^{-1})

As we can see, after 5 · 60 s at temperature of 98 ± 2°C the sauces' effective viscosity decreases insignificantly, and it decreases approximately by 10% during (10…15)· 60^{-1} s for topping «Berry mix» and filling «Currants», but the sauces' structure is not destroyed.

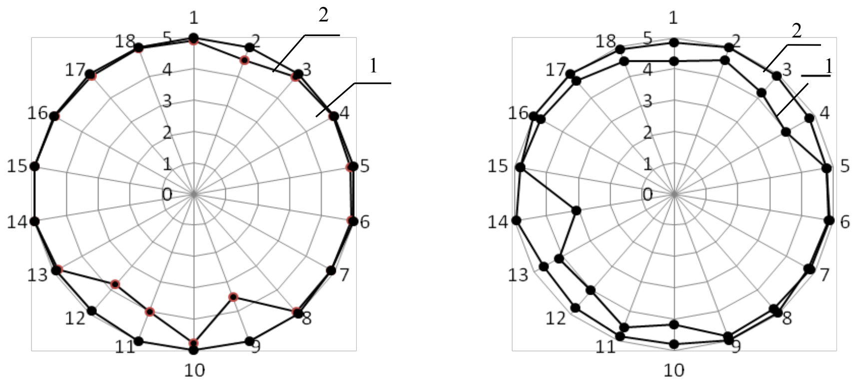
The study results prove the hypothesis about tendency of viscosity values decreasing for all samples, but this tendency is less pronounced for fillings (2). The effective viscosity of the filling under heat treatment decreases, but insignificantly, which is provided by the starch properties; probably the amylopectin content in the starch provides the stable colloidal solutions formation and prevents retrogradation process; the absence of amylose and lipid complexes in starch provides increasing of solubility and water-binding ability of starch grains.

During results studies of reheat treatment organoleptic indices summarizing, it is determined that the consistency of the sauces is more liquid, appearance, color and smell are practically unchanged. Graphically sauces' organoleptic assessment before and after reheat treatment is presented in fig. 3.9, 3.10.



a b

Figure 3.9. Organoleptic profiles of sauces: 1 – sauce «Berry mix» on the base of corn starch (control sample); 2 – sauce «Berry mix» on the base of wax corn starch «Prima»; a – freshly prepared; b – after reheat treatment



a b

Figure 3.10. Organoleptic profiles of sauces: 1 – sauce «Strawberry and banana» on the base of corn starch (control sample); 2 – sauce «Strawberry and banana» on the base of wax corn starch «Prima»;
a – freshly prepared; b – after reheat treatment

During starch-containing products storage process, their evolution occurs: moisture redistribution, compaction, etc. Sauce's effective viscosity changing dynamics were studied for understanding the changes and quality control of finished products. Finished products were stored at temperature of 2…6°C in consumer packaging of thermoplastic polymeric materials in accordance with regulatory documentation for determining and substantiating storage conditions (fig. 3.11).

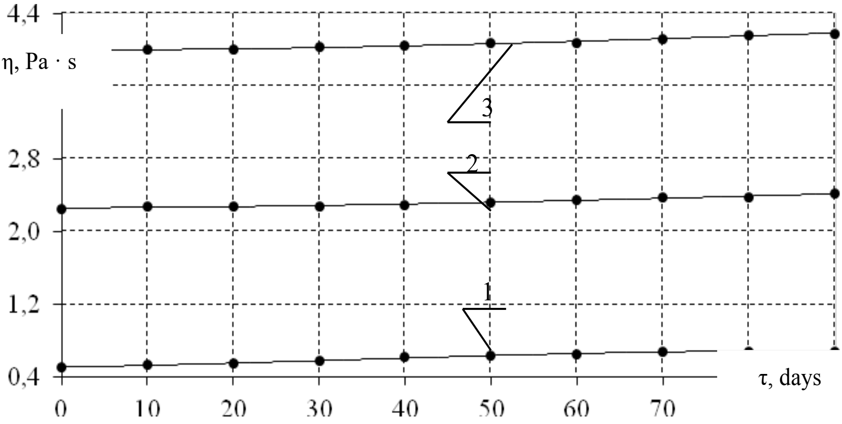


Figure 3.11. Dependence of the sauces' effective viscosity on the storage duration: 1 – dressings; 2 – toppings; 3 – fillings (γ=50s^{-1})

It is established that storage up to 90 days is characterized by slight viscosity increasing: for dressings – from 0,50 ± 0,01 to 0,68 ± 0,2 Pa · s, for toppings – from 2,25 ± 0,06 to 2,41 ± 0,07 Pa · s, for fillings – from 4,00 ± 0,1 to 4,18 ± 0,1 Pa · s.

Thus, the conducted studies prove the possibility of use the developed toppings and fillings in the technologies which involve heat treatment; the maximum time of their heat treatment at temperature of 98 ± 2°C doesn't exceed 30·60 s.

The nutritional value of sauces and toppings is determined by their content of carbohydrates, minerals, etc. (table 3.11). It is found that the total carbohydrate content depends on recipe composition and it is: 23,6% for dressings, 32,0% for homogeneous toppings, 40,0% for toppings with fillers, 53,0% for dips, 57,0% for fillings.

Table 3.11. **The overall chemical composition of sweet sauces**

Index	**Content, %**				
	dressing «Peach»	**topping «Cherry»**	**topping «Berry mix»**	**dip «strawberry and banana»**	**filling «Currants»**
Mass fraction of solids	24,0±0,7	33,7±1,0	42,3±1,3	55,0±1,7	60,0±1,8
Mass fraction of carbo-hydrates, including:	23,6±0,8	31,9±0,9	40,0±1,3	53,0±1,6	57,1±1,6
– mono- and disaccharides	21,3±0,7	28,3±0,7	33,7±0,8	43,9±1,3	47,7±1,4
– starch	2,3±0,07	3,3±0,09	4,8±0,1	7,3±0,2	7,4±0,2
– dietary fiber	traces	traces	1,5±0,04	1,5±0,02	2,0±0,06
Mass fraction of ash	0,2±0,007	0,2±0,007	0,3±0,008	0,3 ±0,008	0,4±0,1
Mass fraction of titrated acids in terms of malic acid	0,7±0,002	1,4±0,04	1,1±0,03	0,4±0,01	1,7±0,05

Other ingredients also show dependence on the recipe composition (sauces' consistency), for example, the starch content, which is about 2,0% for dressings and more than 7,0% for toppings.

The developed sweet sauces mineral composition determining is presented in table 3.12. Mineral composition studies show that the sauce ash residue is represented by both macro- and trace elements, the vast majority of which is potassium (2,9% –8,5%), sodium (0,3 – 0,8%) and phosphorus (0,5 – 0,8%). Among trace elements the manganese content is from 0,2 to 1,4%. In addition, calcium, magnesium and other minerals are also identified.

Safety indices are indispensable priority among all possible product's advantages, their standardization is carried out in Ukrainian Technical Specifications 10.8-01566330-306:2015 «Fruit and berry sweet sauces». The results of microbiological indices studies (table 3.13) show their compliance with the regulatory documentation both after production and during storage.

Table 3.12. **Sweet sauces mineral composition**

Index	**Sauces minerals content**				
	dressing «Peach»	**topping «Cherry»**	**topping «Berry mix»**	**dip «strawberry and banana»**	**filling «Currants»**
Major mineral elements, mg					
Calcium	8,5±0,2	12,3±0,3	10,4±0,3	2,4±0,07	11,9±0,3
Potassium	85,4±2,5	78,8±2,4	58,9±1,7	29,9±0,8	78,3±2,3
Phosphorus	5,8±0,1	9,9±0,3	8,9±0,2	3,8±0,1	10,8±0,3
Magnesium	3,8±0,1	8,2±0,2	6,1±0,1	4,1±0,1	5,3±0,1
Sodium	7,9±0,2	6,8±0,2	4,4±0,1	3,9±0,1	7,3±0,2
Chlorine	0,8±0,02	2,4±0,07	3,6±0,1	-	-
Sulfur	2,2±0,06	1,8±0,05	2,7±0,08	-	-
Trace elements, mcg					
Iron, mg	0,5±0,01	0,18±0,005	0,2±0,007	0,08±0,002	0,2±0,008
Manganese, mg	13,9±0,4	24,5±0,7	36,0±1,08	-	-
Iodine	0,68±0,02	0,6±0,01	254,9±7,6	-	-
Chrome	0,8±0,02	-	0,8±0,02	-	-
Fluorine	3,8±0,1	3,9±0,11	1,8±0,05	-	-
Molybdenum	1,3±0,03	-	3,0±0,09	-	-
Boron	75,8±2,3	38,3±1,1	40,0±1,2	-	-
Cobalt	0,3±0,01	0,3±0,009	0,3±0,01	-	-
Nickel	3,7±0,11	-	1,7±0,05	-	-
Rubidium	13,8±0,4	-	8,9±0,2	-	-

Studies show that sauces' microbiological parameters meet the requirements of the regulatory documentation: during certain shelf life it is found that bacteria of the group of Escherichia coli, Staph. Aureus, fungi and pathogens are not identified in 1 g and 25 g of sweet sauces, respectively, and number of mesophilic aerobic and facultative anaerobic microorganisms is $1{,}0\times10^2$ in 1 g, which does not exceed the approved limits.

The product's radionuclide content doesn't exceed the permissible levels, which are approved by Hygienic Regulations 6.6.1.1.-130-2006 «The permissible levels of cesium – 137 and strontium – 90 radionuclide content in food products and drinking water» [142] (table 3.14).

Table 3.13. **The results of sweet sauces microbiological studies**

Index	**According to regulatory documentation**	**Actual content during storage, days**			
		0	**30**	**60**	**90**
Pathogens, in particular, *Salmonella* genus in 25 g of the product	it is not allowed	it is not identified	it is not identified	it is not identified	it is not identified
Mesophilic aerobic and facultative anaerobic microorganisms CFU in 1 g of the product, not more than	$1,0 \cdot 10^3$	$1,0 \cdot 10^2$	$1,0 \cdot 10^2$	$1,1 \cdot 10^2$	$1,5 \cdot 10^2$
Bacteria of Escherichia coli group (coliforms) in 1 g of the product (cm^3)	it is not allowed	it is not identified	it is not identified	it is not identified	it is not identified
S/aureus in 1 g of the product (cm^3)	it is not allowed	it is not identified	it is not identified	it is not identified	it is not identified
Proteus in 0,1 g of the product (cm^3)	it is not allowed	it is not identified	it is not identified	it is not identified	it is not identified

Table 3.14. **The results of the radiant sauce of licorice sauce**

Index	**Permissible levels, Bq/kg**	**Actual value, mg/kg**
^{137}Cs	not more than 140	127±3,0
^{90}Sr	not more than 20	8±0,2

The toxicological studies results (table 3.15) indicate that sauces are fully compliant with regulatory requirements for these safety indices.

Table 3.15. **The results of sweet sauces toxicological studies**

Index name	Index value	
	permissible levels, mg/kg, not more than	actual content, mg / kg
Toxic elements:		
Lead	0,4	it is not identified
Arsenic	0,2	it is not identified
Cadmium	0,03	it is not identified
Mercury	0,02	it is not identified
Copper	5,0	it is not identified
Zinc	10	it is not identified
Patulin mycotoxin	0,05	it is not identified

3.4. Recommendations development of sweet sauces use in the culinary products technology

Research results summarizing leads to the development of recommendations for sweet sauces use in culinary products composition. Conducted studies of sweet sauces quality and safety main indices, their changes under the effect of technological factors determining allow the statement that new products withstand mechanical impact (stirring), reheating, freezing-thawing processes, and therefore they may be recommended for use in a wide range of dessert products.

Today, dessert products become more and more popular among consumers, which stimulates their production both in restaurant business enterprises and in the food industry. For example, industrial production dessert products are represented by dairy products (on the base of yogurt, cheese), fruit and berry desserts, creams. The range of dessert products which are produced by domestic producers is mainly represented by sweet creamed curds and drinking desserts. The shelf life of the products is quite variable and ranges from 7 to 14 days for sweet creamed curd, from 14 days to 5 months for yoghurts, from 3 to 5 months for puddings.

The most popular desserts in the restaurant business enterprises today are creams, mousses, fruit-and-eggwhite jellies, soufflé, cheesecakes and many other dishes; their range can be significantly expanded by adding sweet sauces on the base of fruit and berry raw material.

During technological development the recipe composition and technology of cold and hot sweet dishes (desserts) production with sweet sauces use were elaborated. The content and sequence of sweet sauces introduction into the recipe mixture is substantiated for each group. During the tasting meeting it is proved that sauces' use allows obtaining more juicy dishes, providing them with new taste characteristics and creativity (fig. 3.12).

But the sweet sauces use is not limited by the specified dishes range and it can be significantly expanded according to the wishes and taste preferences of consumers. So, nowadays, dishes with combination of meat, fish and vegetable raw material with fruit and berry sauces use become increasingly popular.

Production technological scheme of dessert «Strawberry cream» with addition of sweet sauce «Berry mix» is presented in fig. 3.13.

Sauces with thick consistency («Currant», «Strawberry and banana») can be recommended for reheating products (stuffed dishes, flour culinary and confectionery products). The heat stability of dressing sauces allows to recommend them for use during fruit, meat and fish raw material stewing.

Production technological scheme of curd pudding with developed filling «Currants» addition is presented in fig. 3.14.

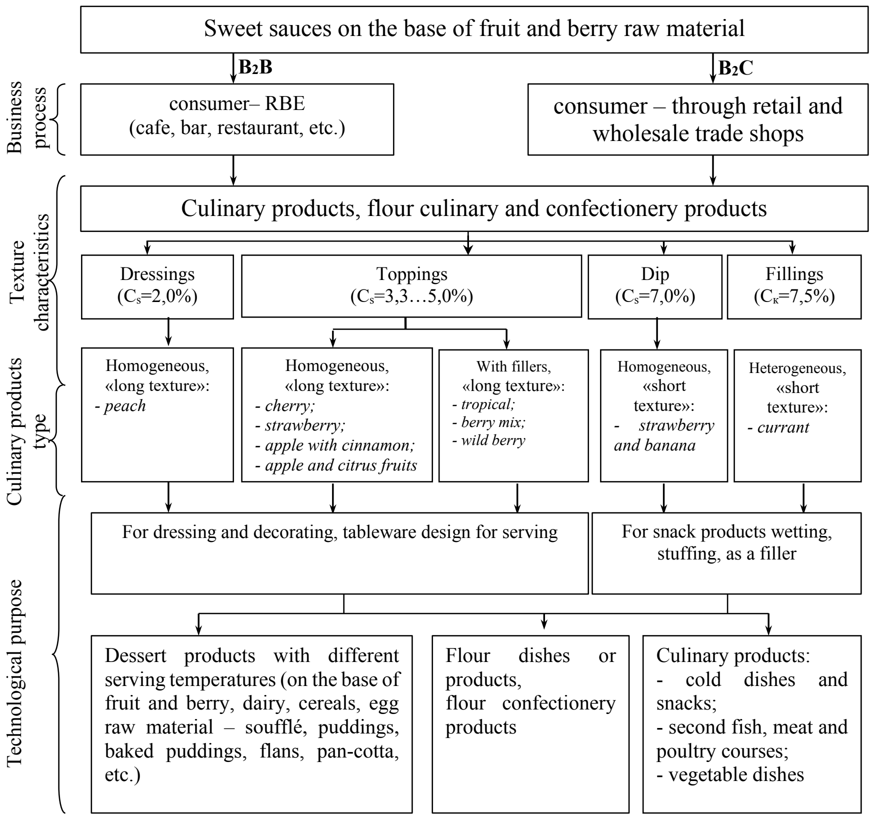


Figure 3.12. General recommendations for use of sweet sauces as part of culinary products

During technological development, filling rational content and amount of released during heat treatment moisture are determined, in particular, from such components as curd, semolina, eggs, sugar, which is taken into account in the recipe composition for desired viscosity and colloid stability providing.

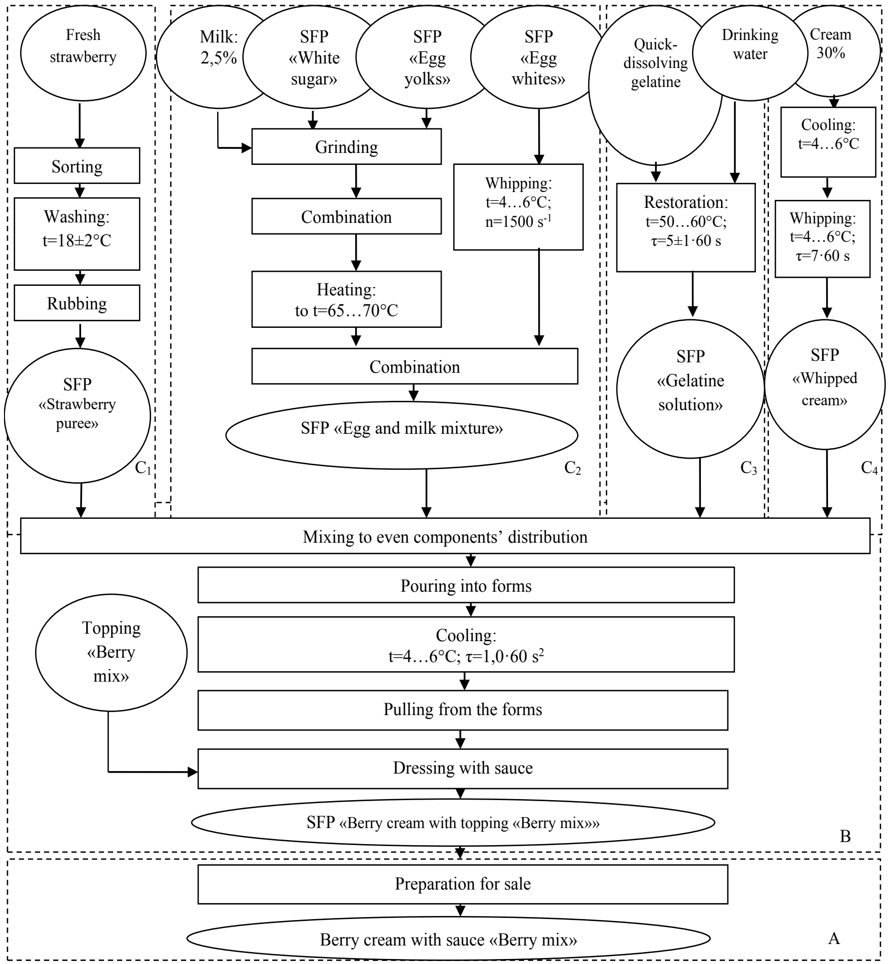


Figure 3.13. Production technological scheme of berry cream with topping «Berry mix»

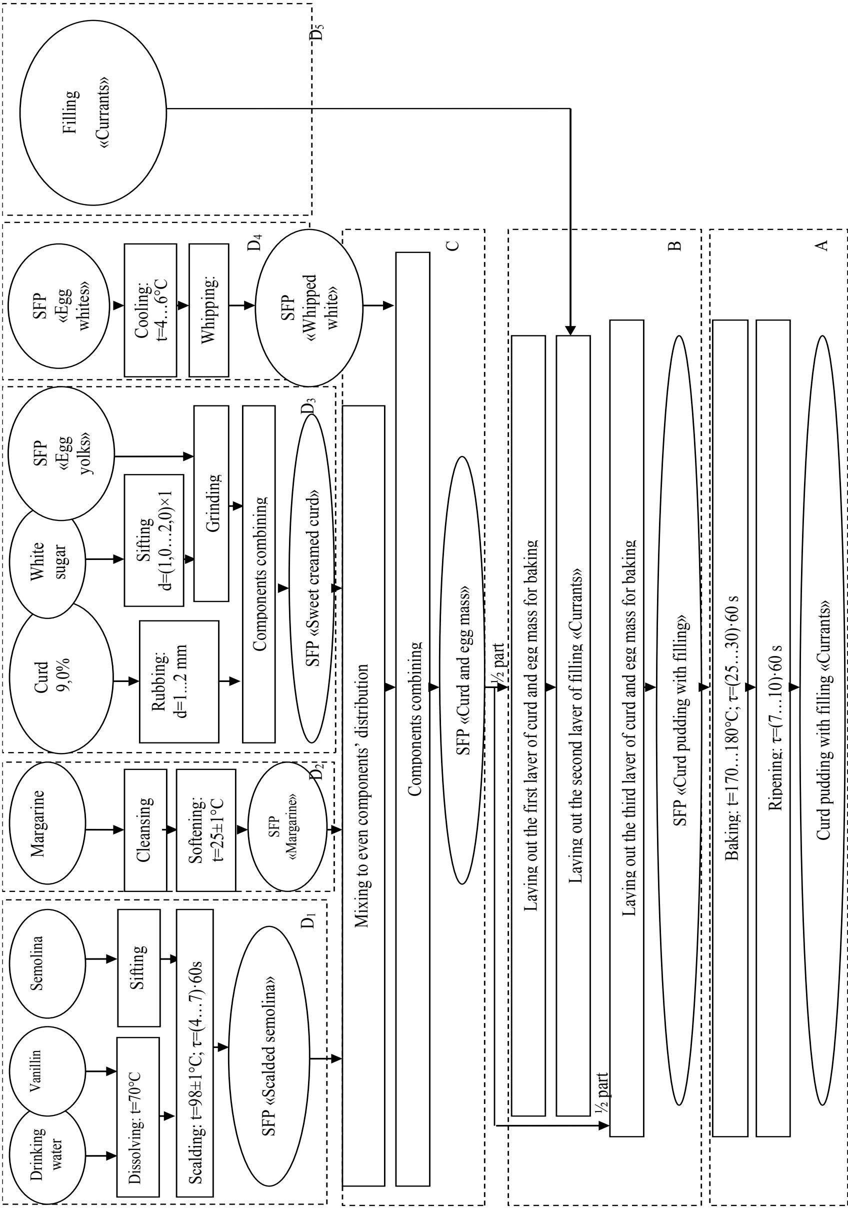


Figure 3.14. Production technological scheme of curd pudding with filling «Currants»

The production technological system of curd pudding with filling «Currants» use consists of the following subsystems: A – «Formation of curd pudding with filling «Currants»»; B – «Semi-finished product formation of curd pudding with filling «Currants»»; C – «Formation of curd and egg mass semi-finished product»; D_1 – «Formation of scalded semolina semi-finished product»; D_2 – «Formation of prepared margarine semi-finished product»; D_3 – «Formation of sweet creamed curd semi-finished product»; D_4 – «Formation of whipped white semi-finished product»; D_4 – «Formation of filling «Currants» semi-finished product».

CONCLUSIONS

1. Sweet sauces development relevance and physical modification starches use prospect are determined by information sources analytical review, scientific and technical information generalization, monitoring current trends of the sauces technologies development.

2. The scientific and practical concept of the sweet sauces technology is developed and experimentally proved, within which the requirements for organoleptic, structural and mechanical and other parameters are formulated with taking into account their technological purpose: for dressings (liquid), toppings (medium thickness), dips, fillings (thick).

3. The interrelation between starch grains average size, their content in amylose and amylopectin composition, as well as starch dispersions gelatinization parameters with taking into account their technological stability providing is determined. Microstructural characteristics studies of PMS determine that wax corn starch «Prima» and tapioca starch «Endura» are characterized by more clearly defined monodispersity (40 – 43% are grains with size from 16 ± 1 to 20 ± 1 μm). The optical thickness of SS is studied and it is shown that starches have different amylose and amylopectin content. It is found that the smallest amount of amylose (traces) is in amylopectin corn starch and wax corn starch «Prima»; correlation between amylose content and grain size is weak.

4. The hydrodynamic changes of GSD parameters are determined depending on the temperature and starch type. It is established that GSD on the base of tapioca starch «Endura», «Indulge» and wax corn starch «Prima» are more resistant to temperature compared to corn and corn e amylopectin starches. The minimum and maximum viscosities (η_{min} and η_{max}) have close values (920 – 1000 Brabender units), which indicates GSD structure stability.

5. The change regularities of physical and chemical, structural and mechanical and functional and technological properties of gelatinized dispersions on the base of PMS under technological factors effect were studied. The influence regularities of white sugar, citric acid, mineral salts, pectin on the hydrodynamic parameters of gelatinization and the functional and technological properties of food systems on the base of PMS and fruit and berry raw material were established. It is determined that GSD on the base of «Prima», «Endura» starches show stability under interacting with citric acid and white sugar (stability factor is 1,0). Effective viscosity under sugar presence of 5 – 30% is characterized by values increasing in 1,5 times. The recipe mixtures pH limits, which are no less than 3,0, are determined.

6. It is proved that GSD on the base of «Prima», «Endura» starches are the most heat-resistant in the cycle «heating – cooling – reheating», their viscosity after reheating decreases insignificantly.

7. It is experimentally proved that starch content control allows the creation of GSD with properties of liquid dispersions (from 2,0 to 3,0%), medium thickness dispersions (from 3,5 to 8,0%) and thick dispersions (from 7,0 to 8,0) %), which

are fixed as parameters of the sauces with variable consistency recipe composition. Reference consistency values (effective viscosity) of the sauces are determined: for dressing – 0,78 ± 0,03 Pa·s with starch content of 2,0 – 2,5%; for toppings with homogeneous structure – 1,60 ± 0,04 Pa·s with starch content of 3,0 – 4,0%; for toppings with heterogeneous structure – 2,70 ± 0,08 Pa·s with starch content of 4,5 – 6,5%; for dips – 3,25 ± 0,09 Pa·s with starch content of 7,0; for the toppings – 3,50 – 3,83 Pa·s with starch content of 7,5 – 8,0%.

8. The recipe composition and technological scheme of sweet sauces production, certain technological operations parameters are scientifically substantiated on the base of analytical and experimental data generalization. New technology of sweet sauces production with PMS use and consistency variable assortment (dressings, toppings, dips, toppings), which consists of 10 names, were developed.

9. The substantiation and normalization of the quality and safety indices for the sweet sauces are carried out, the finished products storage conditions and terms are determined, which are 90 days under temperature of 1...6°C and relative humidity of 75,0 – 85,0%.

10. Recommendations for sweet sauces use in the technologies of culinary products, flour culinary and confectionery products were developed.

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APPENDICES

Appendix A
The experiment matrix for model systems optimization determining

Experiment matrix

$$F := \begin{pmatrix} 1 & -1 & -1 & 1 & 1 & 1 \\ 1 & -1 & 1 & 1 & 1 & -1 \\ 1 & 1 & -1 & 1 & 1 & -1 \\ 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & -1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 1 & 0 \\ 1 & 0 & -1 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 & 0 & 0 \end{pmatrix}$$

Experiment data

$$Y1 := \begin{pmatrix} 1.5 \\ 1.6 \\ 1.9 \\ 2.1 \\ 2.0 \\ 1.6 \\ 1.8 \\ 1.7 \\ 1.8 \end{pmatrix} \quad Y2 := \begin{pmatrix} 1.2 \\ 1.4 \\ 1.78 \\ 1.83 \\ 1.81 \\ 2.3 \\ 1.8 \\ 1.4 \\ 1.5 \end{pmatrix} \quad Y3 := \begin{pmatrix} 0.6 \\ 0.9 \\ 0.7 \\ 1.0 \\ 1.0 \\ 0.7 \\ 1.0 \\ 0.8 \\ 0.9 \end{pmatrix}$$

$$a1 := \left(F^T \cdot F\right)^{-1} \cdot F^T \cdot Y1 \quad a2 := \left(F^T \cdot F\right)^{-1} \cdot F^T \cdot Y2 \quad a3 := \left(F^T \cdot F\right)^{-1} \cdot F^T \cdot Y3$$

Model coefficients

$$a1 = \begin{pmatrix} 1.789 \\ 0.217 \\ 0.067 \\ 0.017 \\ -0.033 \\ 0.025 \end{pmatrix} \quad a2 = \begin{pmatrix} 1.768 \\ 0.087 \\ 0.108 \\ 0.153 \\ -0.302 \\ -0.037 \end{pmatrix} \quad a3 = \begin{pmatrix} 0.922 \\ 0.083 \\ 0.133 \\ -0.083 \\ -0.033 \\ 0 \end{pmatrix}$$

$$F \cdot a1 = \begin{pmatrix} 1.514 \\ 1.597 \\ 1.897 \\ 2.081 \\ 2.022 \\ 1.589 \\ 1.822 \\ 1.689 \\ 1.789 \end{pmatrix} \quad F \cdot a2 = \begin{pmatrix} 1.387 \\ 1.679 \\ 1.635 \\ 1.777 \\ 2.008 \\ 1.834 \\ 1.574 \\ 1.358 \\ 1.768 \end{pmatrix} \quad F \cdot a3 = \begin{pmatrix} 0.589 \\ 0.856 \\ 0.756 \\ 1.022 \\ 0.922 \\ 0.756 \\ 1.022 \\ 0.756 \\ 0.922 \end{pmatrix}$$

Model for starch «Prima» assessment

$$Y1(X1,X2) := a1_0 + a1_1 \cdot X1 + a1_2 \cdot X2 + a1_3 \cdot X1^2 + a1_4 \cdot X2^2 + a1_5 \cdot X1 \cdot X2$$

$$Y1e(x1,x2) := 1.061 + 5.17 \cdot 10^{-3} \cdot x1 + 0.195 x2 + 5.55 \cdot 10^{-5} \cdot x1^2 - 1.95 \cdot 10^{-2} x2^2 + 1.09 \cdot 10^{-3} \cdot x1 \cdot x2$$

Model for starch «Endura» assessment

$$Y2(X1,X2) := a2_0 + a2_1 \cdot X1 + a2_2 \cdot X2 + a2_3 \cdot X1^2 + a2_4 \cdot X2^2 + a2_5 \cdot X1 \cdot X2$$

$$Y1e(x1,x2) := 1.061 + 5.17 \cdot 10^{-3} \cdot x1 + 0.195 x2 + 5.55 \cdot 10^{-5} \cdot x1^2 - 1.95 \cdot 10^{-2} x2^2 + 1.09 \cdot 10^{-3} \cdot x1 \cdot x2$$

Model for amylopectin starch assessment

$$Y3(X1,X2) := a3_0 + a3_1 \cdot X1 + a3_2 \cdot X2 + a3_3 \cdot X1^2 + a3_4 \cdot X2^2 + a3_5 \cdot X1 \cdot X2$$

$$Y1e(x1,x2) := 1.061 + 5.17 \cdot 10^{-3} \cdot x1 + 0.195 x2 + 5.55 \cdot 10^{-5} \cdot x1^2 - 1.95 \cdot 10^{-2} x2^2 + 1.09 \cdot 10^{-3} \cdot x1 \cdot x2$$

Appendix B

Table B.1. **Texture characteristics of model systems on the base of starch**

MS type	MS composition, %	Characteristic	Indices
1	2	3	4
MS for dressings (t=14±2°C)	water – 87,0; starch «Prime» – 2,5%; sugar – 10,0%; citric acid – 0,5%	Appearance	MS surface texture is smooth, transparent, homogeneous, glossy
		Physical indices at rest state	MS is viscous and fluid
		Flow characteristics	Texture is fast fluid «long»
		The fluid flow nature	Non-Newtonian
		Enveloping ability	It can not be on a horizontal surface, it becomes liquid under heating
	water – 87,0%; starch «Endura» – 2,5%; sugar – 10,%; citric acid – 0,5%	Appearance	MS surface texture is smooth, transparent, homogeneous, glossy
		Physical indices at rest state	MS is liquid
		Flow characteristics	Texture is fast fluid «long»
		The fluid flow nature	Newtonian
		Enveloping ability	It can not be on a horizontal surface, it becomes liquid under heating
	water – 87,0%; starch «Indulge» – 2,5%; sugar – 10,%; citric acid – 0,5%	Appearance	MS surface texture is smooth, turbid, homogeneous, matt
		Physical indices at rest state	MS is liquid
		Flow characteristics	Texture is fast fluid «long»
		The fluid flow nature	Newtonian
		Enveloping ability	It can not be on a horizontal surface, it becomes liquid under heating

Continuation of the table B.1.

1	2	3	4
MS for toppings (t=14±2°C)	water – 74,25; starch «Prime» – 5,0%; sugar – 20,0%; citric acid – 0,75%	Appearance	MS surface texture is smooth, transparent, homogeneous, glossy
		Physical indices at rest state	MS is viscous and fluid, elastic
		Flow characteristics	Texture is slow fluid «long»
		The fluid flow nature	Bingham
		Enveloping ability	It can not be on a horizontal surface, it becomes liquid under heating
	water – 78,75; starch «Endura» – 5,5%; sugar – 15,0%; citric acid – 0,75%	Appearance	MS surface texture is smooth, transparent, homogeneous, glossy
		Physical indices at rest state	MS is viscous and fluid
		Flow characteristics	Texture is slow fluid «long»
		The fluid flow nature	Bingham
		Enveloping ability	It can not be on a horizontal surface, it becomes liquid under heating
	water – 78,25; starch «Indulge» – 6,0%; sugar – 15,0%; citric acid – 0,75%	Appearance	MS surface texture is smooth, turbid, homogeneous, matt
		Physical indices at rest state	MS is viscous and fluid
		Flow characteristics	Texture is slow fluid «long»
		The fluid flow nature	Bingham
		Enveloping ability	It can not be on a horizontal surface, it becomes liquid under heating

Continuation of the table B.1.

1	2	3	4
MS for dips, fillings (t=14±2°C)	water – 59,0%; starch «Prime» – 8,0%; sugar – 30,0%; citric acid – 1,0%	Appearance	MS surface texture is smooth, transparent, homogeneous, glossy
		Physical indices at rest state	MS is gel-like, elastic
		Flow characteristics	Fluidity limit is absent, «short»
		The fluid flow nature	Thixotropic
		Enveloping ability	It can be on a horizontal surface, it becomes liquid under heating
	water – 71,0; starch «Endura» – 8,5%; sugar – 20,0%; citric acid – 0,5%	Appearance	MS surface texture is smooth, transparent, homogeneous, glossy
		Physical indices at rest state	MS is viscous and elastic
		Flow characteristics	Fluidity limit is absent, «short»
		The fluid flow nature	Thixotropic
		Enveloping ability	It can be on a horizontal surface, it becomes liquid under heating
	water – 71,0; starch «Indulge» – 8,5%; sugar – 20,0%; citric acid – 0,5%	Appearance	MS surface texture is smooth, turbid, homogeneous, matt
		Physical indices at rest state	MS is viscous and fluid
		Flow characteristics	Fluidity limit is absent, «short»
		The fluid flow nature	Bingham
		Enveloping ability	It can not be on a horizontal surface, it becomes liquid under heating

MONOGRAPH

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