THE LEVEL OF DEVELOPMENT OF SCIENCE AND TECHNOLOGY IN THE XXI CENTURY

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THEORY AND PRACTICE OF PRODUCING DESSERTS WITH FOAM-LIKE STRUCTURE: MOUSSE TECHNOLOGY UTILIZING WHEAT STARCH

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DER STAND DER ENTWICKLUNG VON WISSENSCHAFT UND TECHNIK IM XXI JAHRHUNDERTS

THEORIE UND PRAXIS DER HERSTELLUNG VON DESSERTS MIT SCHAUMARTIGER STRUKTUR: MOUSSE-TECHNOLOGIE UNTER VERWENDUNG VON WEIZENSTÄRKE

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INTRODUCTION

The contemporary restaurant industry is undergoing a phase of active exploration for novel technological solutions aimed at enhancing the assortment and quality of products. Particular attention is warranted for the segment of sweet dishes with a foam-like structure, encompassing mousses, soufflés, ice cream foams, and other desserts. These dishes combine aesthetic appeal with substantial potential for creative experimentation by technologists. Concurrently, their production is associated with a range of technological challenges, including ensuring foam stability, controlling physicochemical parameters, microbiological safety, and organoleptic characteristics.

In modern scientific research, increasing emphasis is placed on identifying functional ingredients that simultaneously serve as stabilizers and impart novel properties to food products. One such ingredient is wheat starch—a natural polymer that is accessible, safe, and technologically versatile. Its application in mousse production opens avenues for improving the stability of foam-like systems, forming structures with novel characteristics, and optimizing technological processes.

This monograph is dedicated to a comprehensive study of mousse technology utilizing wheat starch. It systematizes contemporary trends in the development of the dessert segment with foam-like structures, delineates key problems, and outlines innovative approaches to their resolution. Special attention is devoted to analytical and experimental investigations aimed at determining optimal concentrations of surfactants and starch, thermal processing regimes, and recipe combinations.

The research findings presented in the monograph hold both theoretical and practical significance. They enable a deeper understanding of the mechanisms underlying foam formation and stabilization, contribute to the refinement of technological processes, and facilitate the development of next-generation mousse technologies. For practitioners in the restaurant industry, these materials are of interest as exemplars of implementing scientific developments into daily production activities, which prospectively enhances the competitiveness of food establishments.

Thus, the presented work constitutes a substantial contribution to the advancement of food technologies, particularly in the direction of developing innovative desserts, and may serve as a theoretical and methodological foundation for further scientific research, educational processes, and practical applications in the restaurant industry sphere.

KAPITEL 1 / *CHAPTER 1*
CURRENT TRENDS IN THE PRODUCTION OF SWEET DISHES WITH A FOAMY STRUCTURE

The problem of quality nutrition for the population is multifaceted and includes socio-economic, medico-biological, scientific-technical, organizational-production, and controlling components.

It should be noted that in modern market conditions of economic activity, significant changes have undergone the fundamental economic, technological, and other principles of food service establishments (FSEs). The main goal of their functioning is the production of competitive products, which is based on innovations in the field of marketing, production and sales management, quality and safety management systems, etc.

In all developed countries, the restaurant business is one of the most prioritized sectors for investment. Today, the Ukrainian restaurant industry market cannot be considered fully formed. Due to general economic growth, it is developing quite dynamically, but is still far from saturation. Consumers are offered a wide selection of concepts designed for different income levels and social demands. Demand generates supply, and investments that yield profit are being made in the restaurant business worldwide.

Therefore, the development and implementation of innovative technologies for culinary products is a relevant task.

FSEs constitute a crucial link in the supply chain through which products from the processing and food industries of the agro-industrial complex are delivered directly to consumers. The organization of rational nutrition on a scientific basis and the provision of the population with food products for prophylactic, special, and functional purposes can be effectively realized primarily through the FSE system [1, 2, 3].

Under contemporary conditions, the operations of the food industry and FSEs are oriented towards addressing challenges associated with the development and implementation of competitive technologies and the production of goods with

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consistent consumer attributes.

Within the food service sector, a significant proportion of output comprises sweet dishes and beverages, with products exhibiting a foamy structure experiencing the highest consumer demand. Analysis of the operations of existing FSEs has revealed a substantial recent increase in the production of sweet dishes with a foamy structure, accompanied by a broadening of the product range within this category. However, the production and sale of these goods do not fully satisfy consumer needs. Factors constraining their production include labor intensity, the multi-stage nature of the manufacturing process, and the lack of raw materials with stable quality indicators.

Consequently, the creation of novel food technologies plays a significant role in nutrition. Furthermore, the demands of contemporary patrons necessitate the development of new, high-quality products with enhanced nutritional properties.

In the context of globalization processes and Ukraine's integration into the global community, the food industry occupies a significant position, actively incorporating global trends and innovative technologies into its operations. This is evident in the proactive implementation of modern food production technologies, resulting in the attainment of commensurate product quality and enhanced competitiveness.

Analysis of recent research and publications indicates that the quest for effective development strategies within Ukraine's food industry, alongside the mitigation of adverse operational trends, is a pressing concern for numerous leading domestic scholars. These experts highlight issues such as low protein consumption, excessive intake of animal fats, and dietary deficiencies in complex carbohydrates, dietary fiber, minerals, and vitamins. Consequently, scientists in Ukraine and most countries worldwide are focusing on the production of food products capable of maintaining consumer health at an appropriate level and satisfying their nutritional requirements.

FSEs and food industry enterprises (FIEs) play a crucial role in society by fulfilling humanity's nutritional needs. To enhance competitiveness, they must monitor and integrate innovations into their operations to remain leaders in their field and maintain a competitive edge. However, product quality and service are not the sole determinants of development. Many enterprises face accumulated challenges, including a low technical and technological level of production, insufficient rates of fixed asset renewal, high energy and material intensity of production complexes, and the use of obsolete equipment and technologies. These factors collectively impact operational efficiency and hinder the overall development of the food industry.

The FSE and FIE sectors have undergone notable transformations recently. Consequently, to secure substantial profits and maintain a robust image, they must stay abreast of the latest innovations, which typically streamline and enhance their operations. Thus, innovation adoption is paramount for enterprise modernization and the improvement of their competitive standing. Furthermore, innovative food products must exhibit high quality and adhere to existing quality and safety standards to garner widespread consumer demand.

Monitoring both domestic and international sources reveals that scholarly investigations are primarily directed towards the rational utilization of natural resources; the reduction of the energy value of food products through the application of various additives; the enhancement of biological value; and the augmentation of macro- and micronutrient content, specifically selenium, iron, copper, as well as vitamins and dietary fiber [1, 2].

Therefore, the contemporary strategy of the food industry involves leveraging fundamental, applied, and exploratory research and development, alongside novel scientific concepts, to facilitate a transition to qualitatively new technological processes in food production. This shift aims to foster the creation of a new generation of products for mass consumption, as well as for health promotion and preventative purposes, all while being adapted to consumer needs and prevailing market conditions.

The aforementioned considerations fully extend to sweet dessert products, where technological advancements are focused on implementing industrial technologies to support both Business-to-Business (B2B) and Business-to-Customer (B2C) business processes. Within the broad spectrum of dessert offerings, a significant portion comprises dairy-based desserts such as creams, ice cream, flans, and panna cotta, primarily manufactured by food industry enterprises. Food service establishments, however, typically offer a more limited assortment, which incentivizes manufacturers to adopt competitive, resource-saving technologies and contemporary innovative principles for food product creation.

Extensive literature data indicates that innovation within this chosen segment is proceeding in multiple directions: the utilization of semi-finished products with varying degrees of readiness, enhancement of nutritional and biological value, caloric reduction, and the incorporation of diverse texturizers, thickeners, natural sweeteners, sugar substitutes, and other.

Currently, the development and implementation of resource-saving and waste-free food processing technologies are highly relevant in Ukraine. Groundbreaking new technologies have emerged for innovative products featuring gel-like, foam-like, and emulsion structures, with controlled chemical compositions and predictable functional-technological properties. This positions Ukraine at the forefront of 21st-century food production [1, 2, 4].

It is important to note that modern principles for developing high-quality food products are based on the selection and substantiation of specific raw material types in ratios that ensure predictable quality, consumer, and functional properties, as well as maximum balance of nutritional components in the final product's chemical composition.

An analysis of the dessert market indicates a significant increase in production volumes in recent years, primarily driven by consumer demand. This trend is evident in the expansion of specialized FSE networks, which offer consumers an expanded assortment of sweet dishes, both through original compositional solutions and the use of innovative production technologies. However, it should be noted that sweet dishes with a foam-like structure based on fruit and berry raw materials are predominantly found in FSEs, whereas the food industry primarily produces whipped desserts using dairy raw materials or gelatin. Therefore, expanding the segment of sweet dishes with a foam-like structure represents a promising direction requiring further research. Furthermore, the necessity of improving consumer properties, enhancing competitiveness, and ensuring stable quality indicators of products necessitates optimizing composition and improving existing technologies [4, 5, 6, 7, 8].

The structure of foam-like dishes (products) is primarily formed through mechanical whipping and/or gas saturation, followed by stabilization with proteins, fats, and hydrocolloids. For the HoReCa industry, this category is attractive due to its versatile formats (from verrine desserts and individual pastries to entremets and frozen semi-finished products), high service speed (dishes or products are finished upon serving: glazes, velvet sprays, decor), and controllable cost.

Basic assortment and serving formats:

- *Modern cuisine restaurants and gastro-pubs:*
  - tasting portions: mousse as an element of a composition with textural contrasts.
  - savory "espumas" from a siphon: cream, cheese, vegetable, and mushroom-based.
  - fusion variations: mousse with fermented/smoked notes, spicy inserts, and fermented dairy matrices.
- *cafés, coffee shops, and casual dining:*
  - classic individual mousses in glassware: chocolate, berry, lemon, etc.
  - "To-go" mousse pastries: with basic flavors (vanilla, caramel, pistachio, raspberry).
  - lightened/functional versions: based on yogurt, with reduced sugar content, high-protein, or plant-based.
- *professional pastry shops:*
  - entremets (mousse cakes): complex multi-layered cakes with 2-4 mousse layers, inserts (coulis, crème, dacquoise), and glossy mirror glaze or velvet spray.
  - individual pastries/domes: mini-entremets in silicone molds.
  - "no-bake" options: mousse + crumble/sable, popular for banquets and summer menus.
  - frozen semi-finished products: blast freezing of mousse components for consistent production load balancing.

Ukrainian market: demand and supply characteristics

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- demand for "Instagrammable" dishes (products): Mirror glaze, velvet spray, geometric shapes; "three chocolates," mango-passion fruit, and pistachio-raspberry are popular.
- local ingredients and flavors: Black currant, sea buckthorn, raspberry, blueberry, apple, caramel made from boiled condensed milk, honey, poppy seeds, quark cheese.
- seasonal and banquet formats: Blast freezing of mousse components for banquets.
- growth of "healthy alternatives": Gluten-free bases, alternative sweeteners, lactose-free cream, aquafaba.
- technological upgrades: Silicone molds, clean-label stabilizers, control of Aw/pH, vacuum emulsification.

Notable mousse-based dishes and products

- *Classic desserts:*
- Mousse au chocolat — french classic.
- Fruit and berry mousses: lemon, passion fruit, raspberry, black currant.
- Bavarois (bavarian cream): the foundation of modern mousses.
- Semifreddo / Parfait — frozen desserts.
- Entremet "Three Chocolates" — a multi-layered mousse with dark, milk, and white chocolate.
- Yogurt/skyr mousse.
- *Modern pastry hits:*
- Mousses with coulis and crémeux inserts.
- Mirror glaze, velvet spray ("velour").
- Flavored chocolate mousses with coffee, cardamom, yuzu.
- Vegan/plant-based mousses: Coconut cream, tofu, aquafaba, pectins.
- *Savory/Appetizer mousses:*
- Fish mousses: Salmon, cod.
- Seafood mousses: Shrimp, crab.
- Liver mousses: Chicken, duck.

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- Vegetable/cheese mousses: Beetroot–goat cheese, pumpkin-parmesan, pea-mint.

- *Trends Shaping the Assortment:*

- Textural contrasts.
- Clean label and functionality.
- Geometry and replicability.
- Tropical and tart flavor profiles.
- Frozen semi-finished products and blast freezing logistics.
- Plant-based alternatives.

Recommendations for assortment planning

- Core assortment (must-have) for a café/pastry shop: chocolate, tart-fruit, nutty, yogurt, and a vegan option.
- Entremet selection: 2 bestsellers + 1 seasonal flavor.
- Formats: Individual domes + custom-order cakes.
- Finishing semi-finished products: Stored in the freezer for quick assembly.

The assortment of mousse products in the global and Ukrainian HoReCa industry is evolving from classic individual desserts to complex entremets with multi-layered architecture. The Ukrainian market is quickly adapting global trends, combining them with local ingredients. Consistent demand exists for chocolate and tart-fruit profiles, entremets with mirror glazes, as well as light and plant-based options. This presents an opportunity for food service establishments to create a differentiated menu with high profitability and stable quality.

Overall, the assortment matrix for mousse products can be defined by the following formula:

$$Format \times Flavor \times Seasonality$$

This matrix allows for planning the assortment of mousse products based on serving format, flavor profile, and seasonal relevance. An example of the matrix is provided in Table 1.

Table 1 – Mousse product assortment matrix

Product format	Flavor profile	Seasonality	Notes
Portioned dessert (verrin, glass)	Chocolate, caramel, vanilla	Year-round	Basic assortment of cafes, coffee shops
Portioned dessert (fruit and berry)	Raspberry, currant, passion fruit	Spring–summer	Light refreshing desserts
Entreme cake	Three chocolates, pistachio-raspberry, mango-passion fruit	Year-round	Bestsellers for catering and holidays
Mini entreme/domes	Fermented milk, yogurt, citrus	Spring–summer	High demand for seasonal menus
Vegan option	Coconut, yuzu, blueberries	Year-round	Urban audience, healthy menu
Unsweetened mousses (snack bars)	Salmon, liver, beets, goat cheese	Autumn–winter	Banquet and tasting sets

This type of structuring allows an establishment to quickly formulate seasonal offers, balance classic and trendy flavors, and ensure stable quality and HACCP compliance when working with semi-finished products [1, 3, 4].

An analysis of FSE operations reveals that key factors impeding dessert production include the laboriousness and extended duration of their manufacturing processes, coupled with the preparation of recipe components, unstable raw material properties, short shelf and retail lives, and the absence of industrial semi-finished products, among others.

It's important to note that recipe components (Figure 1) not only regulate nutritional value and shape organoleptic indicators, but also function as structure-forming agents, thereby facilitating foaming, thickening, and gelation. The ultimate structure of the finished product is formed through the realization of the functional-technological properties of both the recipe components and any additionally incorporated texturizers. Consequently, the justification for raw material selection in sweet dish production lies in the functional-technological properties and chemical composition of both primary and auxiliary raw materials, which collectively ensure the desired texture and dispersive properties of the final product.

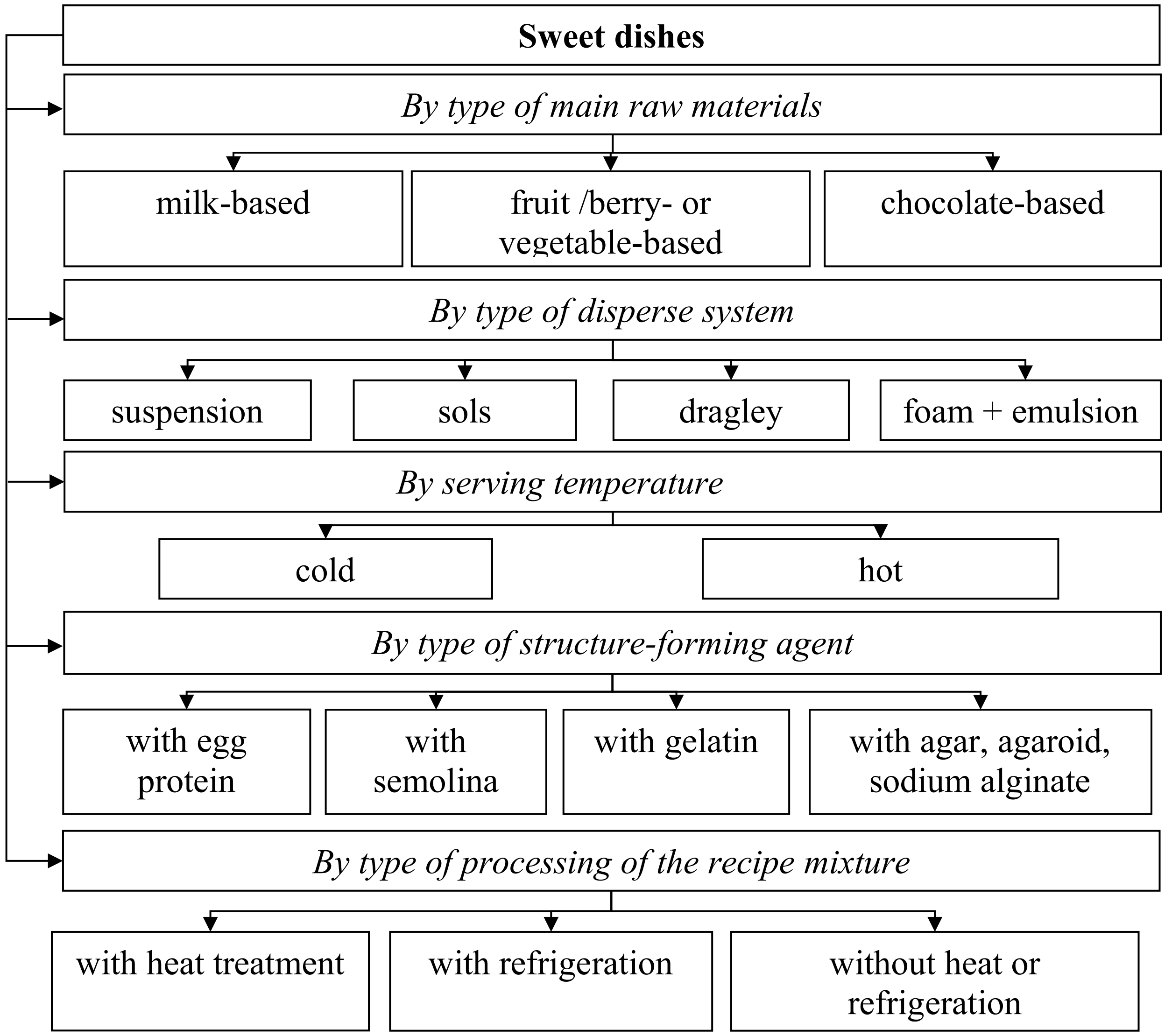

Figure 1 – Classification of sweet dishes

As literature data indicates, the foundation of sweet dishes with a foam-like structure is a whipped formulation blend primarily composed of fruit/berry, vegetable, or dairy raw materials. This blend typically contains an air phase ranging from 30.0% to 45,0%, rendering it thermodynamically unstable and prone to spontaneous degradation. Foam is a critical component in numerous prevalent food products and beverages, including whipped cream, mousses, soufflés, ice cream, bread, pastries, and carbonated drinks. Consequently, research into novel foam types and new foaming and stabilizing agents continues to advance. The presence of bubbles within food structures can significantly influence their texture and contribute to the formation of novel sensory perceptions [9].

Within the scope of this work, mousses present particular scientific interest. A mousse (from French: mousse, meaning "foam") refers to sweet or savory dessert dishes. Traditionally, mousse is prepared from a primary ingredient that defines its character (e.g., fruit or berry juice, purée, wine, chocolate, coffee, cocoa). It also incorporates food substances that facilitate the formation and stabilization of the foam structure (such as egg whites, gelatin, agar) and ingredients that impart or enhance sweetness (e.g., sugar, saccharin, honey, molasses). Occasionally, semolina is used in lieu of egg whites and gelatin due to its excellent swelling and structure-forming properties, allowing it to mimic the desired consistency of the dish.

Consequently, for mousse preparation, raw materials (fruits, berries, vegetables, meat, fish, seafood, liver) are first comminuted to achieve a homogeneous mass, after which they are whipped into a foam. The sweet taste of mousses necessitates a specific content of various sugars in their composition: sucrose, glucose, and fructose.

Mousses are characterized by their delicate flavor, aroma, and consistency, possess an appealing appearance, and are readily and quickly assimilated. Thus, they diversify menu offerings and play a significant role in nutrition.

The nutritional value of mousses is primarily determined by their sugar content. However, sugars should ideally account for approximately one-third of the daily carbohydrate requirement, as excessive quantities can lead to fat deposition, elevated blood cholesterol levels, and other adverse health effects. Mousses also serve as a source of vitamins, mineral salts, and organic acids (e.g., malic, citric, lactic acids). These nutrients are contributed by the raw materials from which the mousses are prepared (e.g., apples, pears, cranberries, melon, milk, cream, chocolate, semolina). Furthermore, mousses are rich in aromatic compounds that develop during preparation. Mousses also contain proteins and fats within their composition.

Fruit and berry raw materials rank among the foremost ingredients useed in mousse technology, including bananas, pineapples, raspberries, strawberries, apples, blueberries, currants, and many others. Among the most prevalent mousse formulations are those incorporating apples, which are rich in pectins and contribute to the foaming process.

The nutritional value of bananas is primarily attributed to their high mass fraction of carbohydrates (18-22%), which in unripe fruits are predominantly represented by starch.

The primary component in mousses responsible for forming the foam structure is poultry egg white protein, whose functional-technological properties are determined by its chemical composition. Another component that also contributes to mousse structure, facilitates gelation and foaming, and influences the nutritional and biological value of mousses is gelatin. Gelatin is a protein product, representing a mixture of linear polypeptides of varying molecular weights, derived from animal sources. Gelatin is produced from bones, tendons, and cartilage through prolonged boiling with water, during which collagen, a constituent of connective tissue, transforms into glutin.

Its composition includes: proteins – 84-86%, fats – 0.1%, moisture – 8-12%, and ash – not more than 2.5%. Its main characteristics are transparency and jelly strength. Structure-forming capacity, foaming capacity, and gelling capacity are the principal characteristics of gelatin exploited in the technology of preparing sweet and savory mousses.

Additionally, mousses incorporate various additives, which are combinations of specially selected functional substances acting as stabilizers and foaming agents [4, 5, 7].

The nutritional value of mousses depends on the main components of the formulation, which, in turn, also define the product assortment. The classification of mousses is presented in Figure 2.

Novel elements in contemporary culinary arts facilitate experimentation with unusual textures, flavor-aroma characteristics, and the creation of chromatic halftones, among other innovations. This expands the boundaries of classical cuisine, opening new avenues for experimentation. Espumas represent a combination of whipped, "aerated dishes" derived from various vegetables and fruits. The range of dishes that can be prepared using this technology from standard raw materials (milk or cream, vegetables, and fruits) is quite extensive (Figure 3).

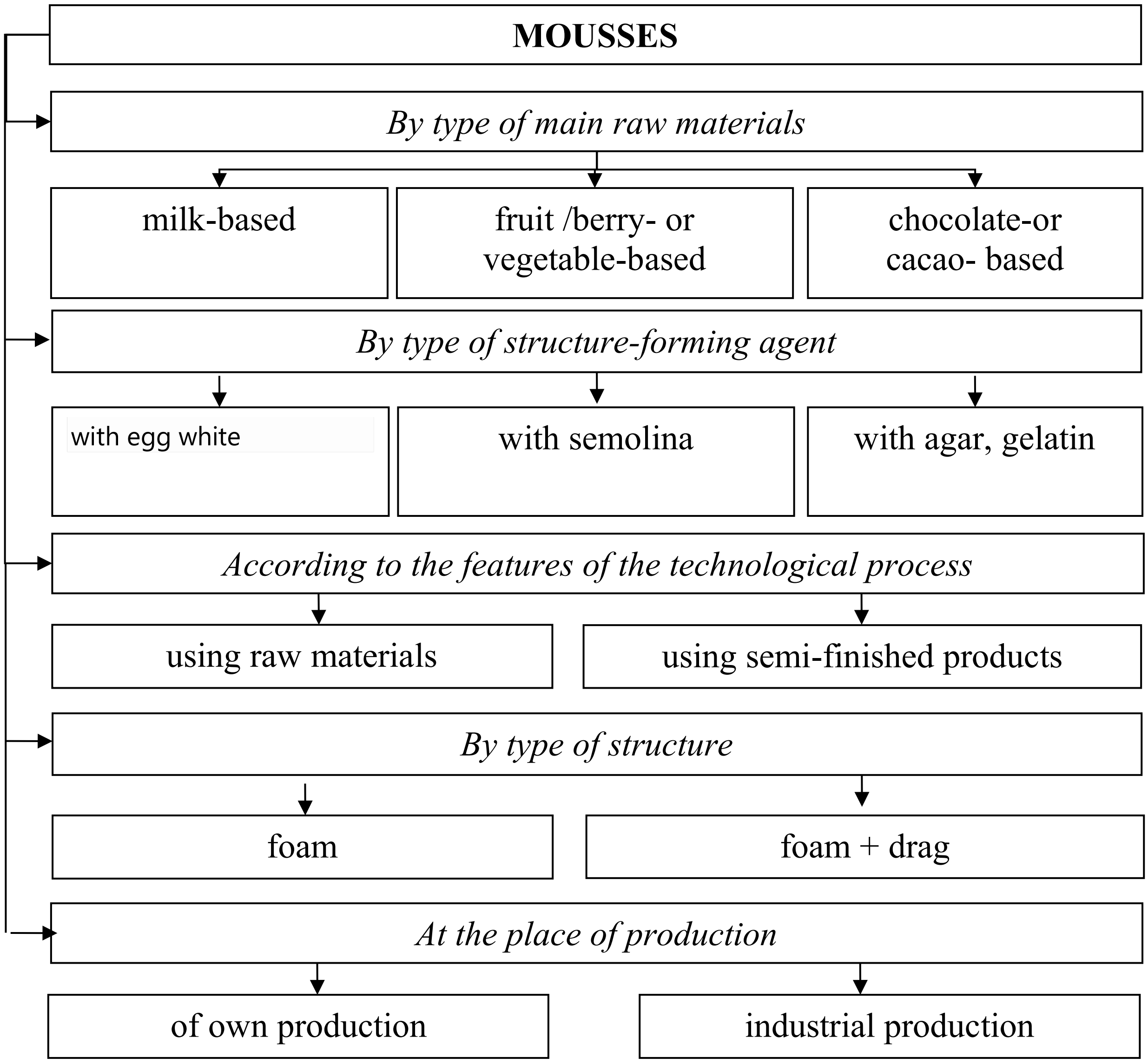

Figure 2 – Classification of mousses

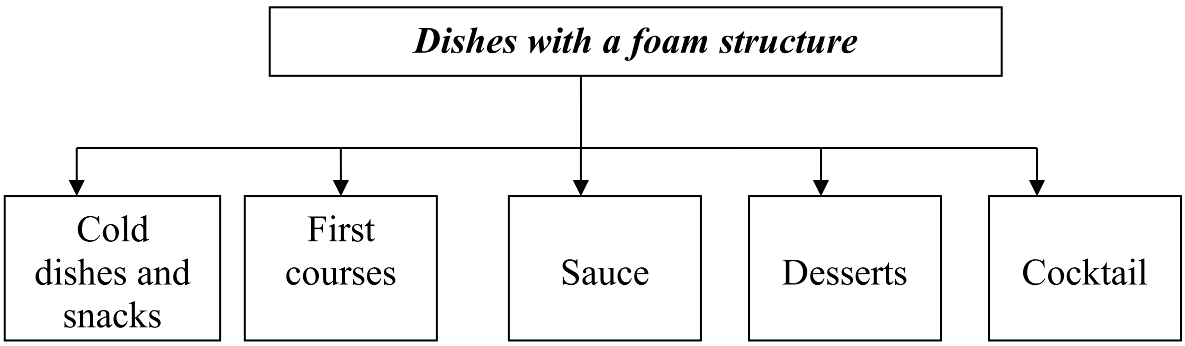

Figure 3 – Directions for the implementation of the technology for obtaining foam structures

Espuma is a light, flavorful, and delicate mass resembling whipped foam. A specialized preparation method ensures the complete preservation of the natural taste, aroma, color, vitamins, and minerals of the dish's ingredients. These dishes can be savory or sweet, single-component or multi-component, but invariably aerated. Ingredients may include fruits, vegetables, herbs, fish, meat, and dairy products.

For the formation of a stable foam, appropriate viscosity of the formulation blend and low surface tension at the liquid-air phase interface are required. Traditionally, egg white, with its low surface tension, is used to produce whipped products with stable foam. This low surface tension reduces the thickness of the medium layer between bubbles, creating a large interfacial area. Concurrently, the viscosity of the mixture impedes the reduction in layer thickness, preventing its rupture and the coalescence of air bubbles.

The stability of protein foam is explained by the structural-mechanical properties of adsorbed layers and the thermodynamic stability of the liquid films of egg white. These properties slow down liquid drainage, reducing the rate of film thinning, which imparts increased viscosity and strength to the film, creating an elastic framework that gives the foam solid-like properties [4, 10, 11].

Additionally, traditional components that form the structure of foam-like dishes, thereby facilitating foaming and gelation, include gelatin, semolina, and pectin.

Surface-active substances (surfactants) represent a promising raw material for sweet dishes with a foam-like structure. They offer several advantages: storage stability, ease of application, inertness to other ingredients in the finished product, and reduced production cost. Their primary application is to ensure high foaming capacity, allowing for controlled foaming processes.

In the production of sweet dishes with a foam-like structure, stabilizers are obligatory components in addition to foaming agents. The use of these substances, and especially their specific compositions, ensures high aeration and structural stability. Beyond their stabilizing effect, they also enhance the foaming capacity. For this purpose, gums of plant and microbiological origin, as well as carrageenans, agar, and other hydrocolloids, are employed. These agents bind a portion of the water in the mixtures, increasing their viscosity and improving their whipping ability, which leads to enhanced structural retention during storage. Stabilizers, depending on their role in system stabilization, are classified as moisture-binding (e.g., gelatin) and gelling (e.g., plant gums, flour, pectin, carrageenan).

Based on the foregoing, it can be concluded that the foaming process of sweet dishes and their stabilization are directly influenced by the presence of both foaming agents and stabilizers. Foaming agents possess the ability to accelerate foam formation and ensure the homogeneous distribution of gas bubbles during intensive mixture processing, as well as to distribute and fix them within the liquid phase. It should be noted that the formation of a foam-like structure in sweet dishes is achieved through the realization of the functional-technological properties of functional ingredients, which can include both formulation components and specially added structure stabilizers.

The quality of the finished product is formed at all stages of its production technology. Many technological parameters that ensure the creation of high-quality products depend on the factors of the production process itself.

Technological factors influencing foaming include: whipping duration, heat treatment, hydromodulus, pH, raw material quality, the addition of supplementary components, equipment characteristics, and others.

One of the essential components in sweet dishes is sugar, which exhibits pronounced dehydrating properties. It is known that sugar negatively impacts surface-active substances, specifically by increasing surface tension and reducing the strength of the interfacial adsorption layer. However, it also acts as a stabilizer in foam systems by increasing the viscosity of the aqueous phase and slowing down bubble movement, thereby contributing to enhanced foam stability.

Another crucial component in sweet dishes with a foam-like structure is citric acid, which improves the foaming capacity and foam stability of protein systems, and also shapes the consumer properties of the finished product.

The whipping parameters of the formulation blend determine the organoleptic characteristics of the finished product, as well as foam stability, resulting in foams with varying dispersed compositions. At the onset of whipping, larger bubbles predominate in the foam; however, extending the whipping duration contributes to a reduction in the size of the dispersed phase. An increase in the diameter of the air bubble dispersed phase leads to a decrease in foam stability and a deterioration of the product's organoleptic properties.

Heat treatment is also a significant technological factor in the production of sweet dishes with a foam-like structure, inducing chemical changes in products and enhancing food digestibility. During heat treatment, animal proteins denature, starch gelatinizes, the mechanical strength of products decreases, and new flavor compounds are formed [4, 10, 12, 13, 14, 15].

Therefore, the technological process of producing sweet dishes with a foam-like structure typically involves foam stabilization, which is achieved through the introduction of stabilizers or specific formulation components such as sugar and acid, or by the application of low temperatures.

Thus, both formulation components and technological factors directly influence the quality of finished products with a foam-like structure. Consequently, investigating their impact and methods of control holds significant scientific and practical interest. The necessity of regulating foam properties to optimize the quality indicators of products with a foam-like structure is also driven by increased demand for such products, as foaming processes are widely applied in the production of mousses, sambucs, puddings, ice cream, and other items.

Analysis of numerous literature sources indicates that the foundation of many sweet dishes is foam, which represents a thermodynamically unstable dispersed system with a highly developed interfacial area, whose formation is accompanied by an increase in the system's free energy.

Foams significantly contribute to the volume and texture of many food products. They impart volume and a characteristic mouthfeel to products like whipped cream and ice cream, and a light, airy texture to baked goods. Improperly formed or unstable foam results in dense, low-volume products that fail to meet consumer expectations [10, 12, 13, 14, 15].

The food industry and FSEs utilize a substantial quantity of foam-like masses, which can be conditionally divided into foams used immediately after preparation (e.g., cocktails, creams) and foams that can be stored for extended periods after technological processing (e.g., marshmallows, fruit pastes).

To date, the theoretical aspects of the foaming process – dependent on ingredient composition, properties, formation and stabilization methods, and the influence of various technological factors – have been investigated by researchers such as Landau L.D., Dickinson E., Hrynchenko H.O., Pyvovarov P.P., Goralchuk A.B., Hnitsevich V.A., Vasilyeva O.O., Doroshkevich R.Yu., Nemirich O.V., Nikiforov R.P., Koretska I.L., and others.

However, despite a considerable body of work, a single, comprehensive theory of foam formation and stabilization does not exist, necessitating further research in this domain. Therefore, we deem it essential to examine the fundamental theoretical principles of the foaming process and its stabilization to obtain sweet dishes with a foam-like structure characterized by excellent whipping capacity and long-term stability.

Foams, or foam-like dispersed systems, are dispersions composed of gas bubbles separated by liquid. They form when a liquid is mixed with a gas or when gas is introduced into it. A dispersion of gas in a liquid where the gas concentration is low and the thickness of the liquid films is comparable to the size of the gas bubbles is referred to as a gaseous emulsion or layered foam.

The structure of foams is primarily determined by the ratio of the gaseous to the liquid phases, and depending on this ratio, foams can exhibit different forms: spherical or polyhedral. Foam cells adopt a near-spherical shape when the volume of the gaseous phase exceeds the liquid volume by no more than 10 to 20 times. In such foams, the bubble films possess a relatively significant thickness. For foams where the ratio of gaseous to liquid phase volumes is several tens or even hundreds, the cells are separated by very thin liquid films, presenting a polyhedral shape. During the aging process of foams, the spherical bubble shape transforms into a polyhedral one.

Two primary methods for foam generation are distinguished:

– dispersive method – this involves intensive agitation of the formulation mixture at atmospheric pressure in the presence of a foaming agent. In this scenario, air is entrained, fragmented into small particles, and the mass viscosity increases, gradually forming a foam.

– condensation method – this involves saturating the mass with gas under excess pressure.

In the dispersive method, foam forms as a result of the intensive co-dispersion of a foamable solution and air.

The condensation method of foam generation is based on altering the physical state parameters of the system, leading to gas supersaturation of the solution (the working medium). This method also encompasses foam formation resulting from chemical reactions and microbiological processes that yield gaseous products.

Foam generation can be attributed to the simultaneous action of multiple foaming sources. For instance, certain technological processes involve operations such as aeration and stirring. It should be noted that the foaming process is quite complex due to the synergistic influence of numerous factors. The regularities characterizing the foam formation process primarily depend on the specific technological conditions.

The main criteria for evaluating foam quality include:

– the volume or height of the foam column under specified experimental conditions;

– the ratio of the foam volume or height to the initial liquid volume;

– the ratio of the foam column height to the time of its complete breakdown;

– the change in foam volume (or column height) over time.

The aforementioned points underscore that no universal criterion exists for the foaming process that unambiguously evaluates all changes occurring within the technological system.

Literary data indicates that "pure" liquids are incapable of forming foams with sufficiently high stability, a conclusion corroborated by numerous scientists based on thermodynamic principles. A single-component system with a sufficiently large surface (film, bubble) rapidly destabilizes regardless of its surface tension value. In such systems, the stabilizing factors characteristic of foams are not exhibited, and their destruction processes occur spontaneously and at a very significant rate. For instance, in the absence of an excess of surfactant molecules in the surface layer, pure liquid films degrade under the influence of gravitational forces even at a relatively substantial thickness [10, 13, 14, 15, 16].

The key properties of foams include the following: foaming capacity of the solution; foam expansion (or overrun); foam stability; foam dispersity.

Foaming capacity of a solution refers to the volume of foam (in mL) or height of the foam column (in mm) formed from a constant solution volume under defined conditions within a given time.

Foam expansion (or overrun) is defined as the ratio of the foam volume to the initial volume of the solution used for its formation.

During the formation of high-expansion foams, bubbles transform into polyhedral cells, and the liquid films become layers a few hundred, sometimes a few tens, of nanometers thick. Such films form a spatial framework possessing a certain elasticity and strength. Consequently, foams exhibit the properties of structured systems.

The foam expansion and its stability are also influenced by:

– the viscosity of the dispersion medium, with an increase in viscosity leading to enhanced foam stability;

– the presence of low-molecular-weight electrolytes in the liquid, which results in reduced foam expansion and stability;

– mechanical stress (shaking, wind) and high temperatures, which also negatively impact foam stability.

Foam stability is its ability to maintain its total volume, dispersed composition, and resist liquid drainage (syneresis). Often, the lifespan of a foam element (an individual bubble, a film) or a defined foam volume is used as a measure of its stability.

Foam dispersity can be characterized by the average bubble size, the bubble size distribution, or the interfacial area of the solutions – representing the amount of gas per unit volume of foam.

To obtain stable foams, the liquid phase must contain at least two components, one of which exhibits surface-active properties and is capable of adsorbing at the phase interfaces.

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From literature sources, it's known that the two most crucial characteristics of foam are foam volume and its stability. Foam volume (or foaming capacity, FC) depends on the foaming agent's ability to adsorb at the phase interface, rapidly reduce surface tension, and the whipping speed. Foam stability (FS), conversely, relies on the foaming agent's capacity to form stable interfacial films and a viscous continuous phase.

The stability of foam is influenced by the following factors: temperature, pH of the medium, the presence of electrolytes, and the presence of foam system stabilizers.

The impact of temperature on foam stability is highly complex and linked to the processes occurring within the system. For example, increasing temperature boosts the evaporation intensity of both the solvent and the foaming substance. Depending on the foaming agent's concentration and structure, foam stability may either increase or decrease.

Foam stabilization is achieved by introducing stabilizers into the solution, which may include carboxymethylcellulose, polyvinyl alcohol, and others. These substances contribute to an increase in the viscosity of the solution and films, thereby slowing down the process of liquid drainage from the foams [14, 15, 16].

The introduction of electrolytes affects the stability of foam bubbles differently. If the adsorption layer is not saturated with surfactant molecules (surfactants), the addition of an electrolyte slightly enhances bubble stability. However, at surfactant concentrations that ensure or exceed saturation of the adsorption layer, the addition of sodium chloride sharply reduces bubble stability. This occurs because a decrease in surfactant concentration in the solution leads to an increase in its surface tension.

Another important characteristic of foam is its dispersity, which determines most of its properties and the processes occurring within it. This is because the kinetics of dispersity change reflect the rate of internal degradation due to coalescence and gas diffusion. There's a correlation between bubble size and foam stability: a specific bubble size range exhibits the highest stability. This optimal range is shifted towards smaller bubbles, which require more energy to produce than larger ones.

Literature presents information on the influence of various factors on foam properties, which can be categorized into three groups:

Factors related to the presence of a foaming agent: These can be colloidal surfactants or high-molecular-weight compounds. It has been established that foaming agents capable of stabilizing oil-in-water (O/W) emulsions exhibit higher foaming capacity. It's important to note that the concentration of the foaming agent plays a crucial role.

Factors related to the properties of the dispersion medium (liquid): Its characteristics are determined by viscosity (higher liquid viscosity leads to more stable foam), pH value, and the presence of low-molecular-weight electrolytes. Active acidity and electrolytes also influence the properties of foaming agents.

Factors related to external influence: These include temperature, liquid evaporation, and mechanical action (vibration, homogenization). It's known that increasing temperature generally degrades foam quality due to increased desorption of foaming agent molecules, more intense liquid evaporation from films, and a decrease in their viscosity. However, for foams formed with high-molecular-weight compounds, heat treatment can lead to a transition of the liquid dispersion medium into a solid-like state, forming a completely stable solid foam.

Another factor affecting foam properties is the conversion of a two-phase foam into a three-phase foam. The mechanism of stabilization in three-phase foams (gas – liquid – solid particles) is explained by the narrowing of Plateau channels.

According to the works of scientists [12, 14, 15] the following classification of factors influencing foam properties and their degradation process is presented (Figure 4).

Authors further notes that the duration of whipping, equipment design, shaft rotation speed, blade shape and arrangement, and the bowl's fill volume significantly impact the quality of the resulting foam. Increasing whipping duration generally leads to an increase in foam volume, its dispersity, and consequently, its stability. Beyond the nature and concentration of the foaming agent, factors such as temperature, viscosity of the dispersion medium, pH of the medium, and surface tension profoundly influence the foam's foaming capacity.

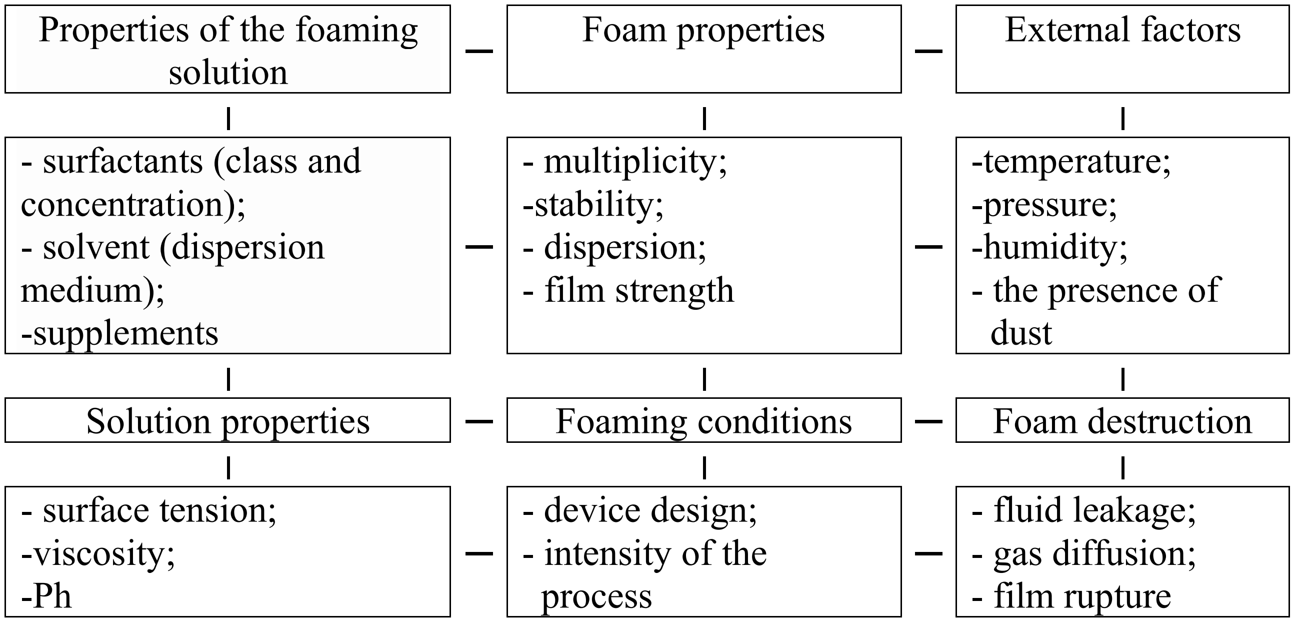

Figure 4 − Factors affecting the properties and destruction of foams

It is known that increasing the foaming agent concentration enhances the foaming capacity of solutions, but only up to certain values. This phenomenon is associated with micelle formation, as the maximum foam volume is observed upon reaching the critical micelle concentration.

Changes in foaming capacity with temperature variations are linked to the influence of a multitude of factors, explaining the diverse behavior of foams as temperature changes.

The viscosity of the dispersion medium is also closely related to the temperature factor. Since dessert formulations with a foam-like structure typically include sugar, an increase in its concentration leads to a more viscous liquid within the foam films, which retards its breakdown and enhances stability. However, sugar's ability to increase the surface tension of solutions significantly complicates their foaming process.

The pH of the medium plays a specific role in the foaming of solutions, particularly protein solutions: foam volume and stability reach their maximum values in the region corresponding to the isoelectric point of the proteins. Solutions of non-ionic surfactants exhibit different behavior; their foaming capacity is independent of pH within the range of 3,0 to 9,0.

Surface tension is a property of the interfacial surface. It has been demonstrated that as the surface tension of solutions decreases, their foaming capacity increases, as less work is required to produce a foam of equivalent volume [10, 13, 14].

Scientists distinguish two types of foam stability:

– kinetic (sedimentation) stability: The ability to maintain an unchanging distribution of dispersed phase particles within the system's volume, i.e., the system's ability to resist gravitational force.

– aggregative stability: The ability to maintain the size (dispersity) and individuality of dispersed phase particles unchanged over time.

Aggregative stability is determined by thermodynamic, kinetic, and structural-mechanical factors, and is based on the research of Landau L.D., Dickinson E., Iorgachova K.G., Dorokhovich V.V., Zubchenko A.V., and others.

According to literature data, foam stability is assessed by three key indicators: resistance to liquid drainage from films (syneresis), change in dispersed composition, and reduction in overall foam volume.

Syneresis exhibits the following characteristics:

– the rate of syneresis is inversely proportional to an increase in the viscosity of the foaming agent solution, inversely proportional to the square of the overrun, and directly proportional to the square of the foam dispersity;

– the rate of syneresis decreases with an increase in foaming agent concentration.

– for identical overrun and dispersity, the rate of syneresis decreases as the foam column height diminishes.

– as temperature decreases, the rate of syneresis increases, despite an increase in solution viscosity. This is attributed to an increase in surface tension, which leads to an increase in the size of foam bubbles [10, 13, 14, 15, 16].

Thus, a crucial aspect in the formation and stabilization of foam-like systems is understanding the forces acting on the foam (Table 2).

First and foremost, gravitational force causes liquid to drain from the films between bubbles. This drainage can be retarded by increasing the viscosity of the solution or by introducing solid particles into the solution. These particles, when lodged

Table 2 − Forces acting on the foam

Natural forces	Effect on foam
Gravity	Drainage of liquid from foam
Pressure difference in films and channels	Leakage of fluid into the channels
Gas pressure difference in bubbles of different sizes	Diffusion of gas from small bubbles
Overlapping double electrical layers	Increased foam stability

in Plateau channels, reduce their "free diameter." Slowing liquid drainage through channel constriction can become a stabilization mechanism for three-phase foams (gas-liquid-solid particles). All the aforementioned foam characteristics determine its structural-mechanical properties. Unlike liquids, foams possess distinct attributes that allow them to be considered structured systems, characterized by properties akin to solids.

Outwardly, this is manifested in the foam's ability to retain its initial shape for a certain period. Evidently, there is a correlation between the structural-mechanical properties of foam, syneresis, and the viscosity of the surface layers. Foams exhibiting lower liquid drainage rates and high viscosity of the adsorption layers possess high viscosity. These properties are characteristic of solutions containing polar organic groups (e.g., saturated fatty alcohols or acids) that readily adsorb at the liquid-gas phase interface.

The instability of foams is caused by an excess of free energy in the surface layer separating the dispersed phase and the dispersion medium, which subsequently deteriorates the organoleptic properties of the finished product. To obtain foam-like products of stable quality, stabilizers are incorporated into their composition, which also contribute to improved foaming properties. To enhance foam stability and the viscosity of whipped systems, substances such as agar and gelatin are added. This achieves the fixation of the formed foam and imparts mechanical strength to it.

The primary factor governing foam stability over time is the stabilizing properties of surfactants. Criteria for evaluating surfactant effectiveness include the magnitude of adsorption at the liquid-gas interface, surface tension reduction, and limiting adsorption. Three main stability factors are identified: kinetic (where film stretching reduces surfactant concentration, leading to increased surface tension and stabilization/contraction of the interfacial surface), structural-mechanical (a significant increase in the viscosity of the interfacial layer compared to the bulk liquid viscosity), and thermodynamic (the appearance of disjoining pressure in the channels resulting from the repulsion of electrical double layers). The kinetic stability factor is associated with the formation of stabilizing surfactant adsorption layers, which reduce the rate of flow through channels and films. Thus, the kinetic stability factor is determined by the elasticity of the film.

Beyond the nature and concentration of the foaming agent, the stability of a foam system is influenced by the pH and the mass fraction of sugar. Most surfactants stabilize foam in an alkaline environment. Experimental data from the authors indicate that sugar has a negative impact on foaming capacity and stability. The decrease in these indicators is affected by both the quantity of sugar and the method of its introduction. The optimal method for adding sugar is to incorporate the full amount at the end of the whipping process, as this has the least detrimental effect on foaming capacity.

Based on the analysis, it can be asserted that the technological principles for ensuring the stable properties of foam-like products are based on the use of functional-technological ingredients (FTIs). These include thickeners, emulsifiers, stabilizers, and foaming agents, among others, which ensure the phase stability of such systems and prevent the sedimentation or coagulation of the dispersed phase.

When selecting a stabilizer, it is crucial to consider whether it will either increase the disjoining pressure in the foam's channels or significantly elevate their viscosity, effectively restricting liquid movement. This can be achieved by understanding the stabilizer's composition and properties, such as its optimal temperature range, pH, and rational concentrations.

The role of stabilizers is typically to increase the viscosity of the dispersion medium. For this reason, they are added to the food system at the final stage of the technological process, once the dispersed system is already formed. Adding the stabilizer at the initial stage is not always feasible, as high system viscosity can complicate, and in some cases, prevent the formation of the desired structure.

An analysis of the literary sources indicated that low temperatures not only positively influence foaming capacity but also partially stabilize the foam. This is explained by an increase in the system's viscosity, which promotes hydrostatic stability, leading to reduced diffusion and absorption of the inter-film liquid. This, in turn, slows down the coalescence of small bubbles into larger ones, which has a less destructive effect on foam stability.

Conversely, an increase in whipping temperature negatively affects foam stability. This is linked to the intensification of thermal vibrations of adsorbed molecules, which weakens the mechanical strength of the surface layer formed by surfactant molecules.

It is essential to note that all the aforementioned factors − the nature and concentration of the foaming agent, temperature, viscosity of the dispersion medium, pH, surface tension of solutions, presence of electrolytes in the liquid phase, and the inclusion of various ingredients as solid particles or fat-containing raw materials − significantly influence foam stability. However, these interactions are specific to different foam-like systems, necessitating individual investigation for each case [10, 13, 14, 15, 16].

It should be highlighted that there is a lack of data in the scientific literature regarding the use of native starches as a foam stabilizer. This underscores the need for research to create scientifically substantiated mechanisms for obtaining stable foam-like systems using starch.

An analysis of operating food service establishments indicates a substantial increase in the production of sweet dishes in recent years, primarily driven by consumer demand for this product category.

This trend is evident in the expansion of specialized FSE networks that offer a broader assortment of sweet dishes, both through original compositional solutions and the use of innovative production technologies.

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However, it must be noted that this product group is primarily available in FSEs. The food industry offers a rather limited assortment, mainly consisting of jellies, whipped milk-based desserts, and milkshakes. Consequently, expanding this segment is a promising direction that warrants further research.

Numerous literature sources confirm that the improvement of technology for this product group is being pursued in multiple directions: the use of semi-finished products of varying readiness, enhancement of nutritional and biological value, calorie reduction, and the incorporation of diverse structure-forming agents, thickeners, natural sweeteners, and sugar substitutes [4, 6, 18].

At the Department of Food Technology of the Open International University of Human Development "Ukraine" (Kyiv), recipes and technology have been developed and implemented for desserts using dry functional mixes such as "AE Panna Cotta Orange," "AE African Dream," and "Creme Brulee." These mixes contain ingredients like carrageenan, locust bean gum, and modified starch, which ensure the product's required stable structure that remains unchanged during a specific storage period.

Numerous studies by experts have demonstrated that the use of natural plant-based raw materials for structure formation not only expands the assortment of food products but also allows for the rejection of chemical food additives and the rational use of local resources.

For instance, the authors established the possibility of using a Jerusalem artichoke and cornelian cherry semi-finished product in the technology of sambucs for up to a 100% replacement of fruit purée, while simultaneously reducing the content of sugar and egg whites. The high aeration is attributed to the presence of high-molecular-weight polymers in the Jerusalem artichoke, such as pectic substances, protein, and dietary fiber, which are capable of strengthening the dish's structure. The optimization of the whipping process for the mixture allowed for the determination of rational indicators of the whipping capacity of the food system using Jerusalem artichoke and cornelian cherry semi-finished product.

Scientists propose the use of Jerusalem artichoke powder in the technology of sweet creams. The resulting creams are characterized by improved consumer characteristics, enhanced nutritional value, and suitability for inclusion in dietary nutrition.

In light of the above, the authors have developed a technology for creams using Jerusalem artichoke powder, cream, cream cheese, and eggs. The choice of raw materials for the production of cream was substantiated, and a technological scheme for its production was developed [18, 19, 20, 21].

A promising direction for expanding the assortment of dessert products is the use of milk-protein semi-finished products with whey and guar gum. Functional mixes enable the production of a product with high-quality indicators. Their use contributes to an increase in the shelf life of finished products, enhanced economic efficiency of production through the use of equipment, and the procurement of a large batch of the semi-finished product, among other benefits.

Additionally, products based on functional semi-finished products are manufactured using a simplified technological scheme. It has been proven that the production of protein-based cream, dairy cream, cocktails, and mousse using a multifunctional semi-finished product allows for a reduction in the duration of the technological process without compromising the finished product's structure [18, 22].

Analyzing modern technologies for sweet dish production, it is necessary to note the improvement of their formulation composition in terms of their vitamin and nutrient content, as well as imparting specific properties. For this purpose, it is expedient to use plant-based raw materials rich in vitamins, macro- and microelements, such as cranberries, sea buckthorn berries, viburnum, and physalis.

The use of plant-based raw materials in the composition of sweet dishes is a highly promising direction, as their chemical composition can enrich this product group with many beneficial substances [4, 23, 24, 25].

With the aim of optimizing the formulation of sweet dishes and enriching them with iodine and selenium, a technology has been developed for a dessert called "Apple Foam," with enhanced biological value, using kelp and Brazilian nut and pumpkin seed meal, and a pumpkin sambuc named "Autumn Delight" with kelp. The developed desserts are products with functional properties that can be recommended for consumption by adults and children for the prevention of thyroid diseases, thereby contributing to the improvement of consumers' health and well-being.

Scientists at Kiev state university of trade and economics have developed a technology for gerodietary dessert products using plant-based compositions (products derived from the processing of algae, cereals, and oilseeds) and a technology for functional beverages utilizing physiologically active raw materials (whey, pectin-zosterin, and a solution of hydrated fullerenes (WRHF – C60HyFn).

Research has established that enriching dessert products and functional beverages with plant-based additives and physiologically active raw materials significantly influences the formation of their quality indicators. Furthermore, it was determined that these raw materials have a positive impact on the organoleptic, physicochemical, and microbiological characteristics of the developed products.

A team of authors has patented a formulation for a whipped sweet dish that includes a dairy base, whole milk, chicken eggs, white sugar, gelatin, vanillin, and water. As the dairy base, cream is used, and in addition, a powder from oranges (or apples) obtained by cold spray drying is incorporated.

Based on an analysis of organoleptic and physicochemical indicators, and chemical composition, the optimal content of orange powder was determined to be within the range of 9,0-11,0% (or 7,0-9,0% for apple powder). This allows for improved consumer properties, providing a foam-like structure and high palatability, while also reducing the energy value and expanding the product assortment in this category.

Scientists believe that a promising direction for developing technology for dishes with a foam structure is the creation of sugar-free products using a wide range of vegetable and berry raw materials (beets, beans, potatoes, cabbage, zucchini, carrots, celery root, horseradish, apples, and cranberries) [4, 23, 26, 27, 28]. For the preparation of sambucs, a vegetable-berry base is first obtained by preliminary heat treatment and homogenization to form a uniform purée. In the second stage, gelatin is dissolved in water, added to the prepared purée, and mixed with egg whites. The mixture is then whipped for 20-25 minutes to create a fluffy foam mass. In the final stage, the finished mixture is cooled and poured into molds at a temperature of 6-8°C. Research into the structural-mechanical indicators of the whipped dishes, specifically dispersity and porosity, revealed that the sambucs are characterized by high dispersity and density, which prevents rapid structural degradation with a lower number of pores. Simultaneously, the finished dishes have a higher porosity, ensuring a foam-like and delicate consistency.

Scientists at the National University of Food Technologies (Kyiv) have developed a technology for whipped desserts of the sambuc type using fruit and vegetable purées, based on agar and pectin of both domestic and foreign origin, which have a preventative health function. Thanks to the addition of apple, pumpkin, and persimmon purées, the sweet dishes are enriched with iodine, acquire radioprotective and antioxidant properties, and their production does not require technological complexity or additional material resources. The authors established that pectin is a more suitable structure-forming agent. The best sambuc quality indicators were obtained with the addition of 6 g of structure-forming agent, 140 g of sugar, and 30 g of invert sugar, while the amount of purée depended on the dry matter content.

Many works by domestic and foreign scientists are dedicated to developing technologies for using milk protein as a foaming agent in whipped sweet dishes. It has been investigated foaming compositions based on sodium caseinate, modified starch, and wheat flour. It was noted that the quality indicators of the foam obtained with these compositions are superior to those of egg white. Whey protein concentrates are widely used in the production of ice cream. The feasibility of using foaming agents − milk-protein concentrates − has been proven in the production of whipped milk desserts [4, 18, 22, 30, 31, 32, 33].

The authors concluded that modern technologies for whipped products do not fully realize the functional-technological potential of skimmed milk (SM) and plant-based raw materials. They propose the advisability of using protein substances from SM and pectic substances from plant-based raw materials in whipped dessert product (WDP) technologies. Based on an analysis of scientific literature, it has been shown that one promising way to use SM in WDP technologies is to concentrate protein substances through thermoacid coagulation, followed by alkaline hydrolysis to convert casein into a soluble state. It was established that plant-based raw materials with an acidic environment can act as a factor in the thermoacid coagulation of SM proteins.

Researchers at the Kharkiv State University of Food and Trade have proposed a method for producing a whipped fermented milk dessert. This method involves preliminary preparation of components, pasteurization of the mixture, mixing with a fermented milk base, adding a sugar and flavor filler mixture, mixing and cooling, whipping, and stabilizing the whipped product. This dessert is distinguished by using a milk-protein concentrate from buttermilk (MPC) as the fermented milk base, buttermilk as the liquid component, and xanthan gum as a structure stabilizer. The xanthan gum is soaked in the buttermilk to swell at a temperature of 30±5°C, dissolved at 35±5°C for 80±10 minutes, and then pasteurized for 5 minutes. The mixture is combined with the prepared MPC in a ratio of 33-40:67-60, whipped for 5-7 minutes, and the structure is stabilized for 2-3 hours. The finished product is characterized by enhanced foaming capacity and foam stability and can be stored for an extended period. This technology can be implemented in both dairy industry enterprises and food service establishments.

In scientific literature, information is found regarding the use of foaming agents, including those from milk and buttermilk. When they are applied, the foam becomes fine-grained and is quite stable. Today, highly effective foaming agents are produced from whey protein concentrates obtained by ultrafiltration and then dried. Such a concentrate is characterized by a high foaming capacity and foam stability. Significant attention is paid to the use of whole blood from slaughtered animals or its plasma as a foaming agent. The use of soy protein hydrolysate contributes to an increased foaming capacity [4, 31, 33].

Researchers have provided scientific substantiation for the composition of various ice creams: creamy, milk-chocolate, creamy with egg, and with vegetable fats and CO_2-extracts. Rational concentrations and ratios of formulation components were established, including milk, cream, skimmed milk powder, butter, milk fat replacer, cryopowders of orange, mango, and mandarin, the sweetener stevia, stabilizer-emulsifiers, flax, rice, corn, and oat flours, whey, and honey. These components ensure high consumer and therapeutic-prophylactic properties of the finished product.

The authors developed a milk dessert with a foam structure using i-carrageenan and k-carrageenan. The whipping process of the formulation mixture is ensured by the presence of surface-active substances in its composition. They propose using modified starch, i-carrageenan, k-carrageenan, agar, xanthan, and high-esterified pectin as structure-forming agents in the dessert. These substances provide stability to colloidal systems, including those with a foam structure based on milk raw materials [34, 35].

Scientists at National university of food technology (Kiev) investigated the properties of modified starches: "MicrolysFH02," "SwelyGelSoft," and "ColdSwell" for their application in the production of sweet dishes with a foam-like structure. It was established that these modified starches are capable of absorbing large quantities of water, exceeding their own mass by a factor of ten. The use of these starches contributes to the stabilization of foam-like structures, while the starch "ColdSwell" significantly improves the foaming process itself. The authors conclude that all the aforementioned starches have a positive effect on foam stability and act as stabilizers for the foam-like structure [36].

Scientific developments by SBU scientists are well-known [37], in which modified starch and xanthan gum are used as food product stabilizers. The technological process involves combining the formulation components, followed by their emulsification, deaeration, pasteurization, packaging, and cooling. The use of modified starch and xanthan gum allows for the creation of products characterized by a stable structure, extended shelf life, and high organoleptic properties [38].

Another innovative direction in the technology of sweet dishes with a foam-like structure is the use of encapsulated products with probiotic properties. The author selected the technology of such sweet dishes as vanilla cream, apple sambuc, and apple mousse with semolina as the subject of research. The nutritional value of these dishes and the content of sugars-glucose, fructose, maltose, and sucrose-were determined.

It was established that the addition of encapsulated products with probiotic microorganisms reduces the quantity of proteins, fats, and carbohydrates, which in turn lowers the energy value, mineral, and vitamin composition of the product. However, it increases the nutritional and biological values due to the microorganisms introduced into the capsule. The properties of these microorganisms include the synthesis of immunoglobulin, vitamins B_6, B_{12}, and K, as well as enzymes that break down fiber, bile acids, proteins, starch, and other substances. They also bind radionuclides and facilitate their removal from the body.

The developed sweet dishes have high organoleptic indicators and are characterized by a moderate price. Additionally, the encapsulated objects do not disrupt the structure of the sweet dishes. The addition of encapsulated probiotic cultures does not affect the gel strength or the foaming capacity of the investigated sweet dishes. The author notes that the only limitation for enriching food systems with probiotic microorganisms contained in an acid-resistant shell is the temperature factor, as living microorganisms die during heat treatment, and the alginate shells are destroyed during freezing.

It should be noted that the developed foam-like sweet dishes with encapsulated bifidobacteria constitute a foam system obtained from two main components: a dairy or fruit/berry base and encapsulated bacteria, which are characterized by neutral organoleptic properties. This allows for a significant expansion of the assortment by varying the flavor fillers and their compositions.

Given new market challenges, a priority area is the search for natural ingredients that contain surfactants and can exhibit foaming, emulsifying, and gelling properties. This approach meets the growing consumer demand for food products that adhere to the "clean label" concept [39].

One example of such an ingredient is pulses, from which isolates, concentrates, starch, flour, and, in recent years, the co-product liquid of the technological process—aquafaba − are obtained [40]. Due to the diffusion of water-soluble nutrients into the cooking medium, aquafaba exhibits functional and technological properties [41], which are a subject of study for both foreign and Ukrainian scientists. Specifically, the foaming capacity of aquafaba was studied in scientific papers [42], while its emulsifying capacity, obtained from various types of pulses grown in Ukraine, was

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investigated in [43, 44].

Among numerous developments and innovations in the technology of sweet dishes with a foam-like structure is a method for producing a long-shelf-life mousse, which contains a controlled "fat-in-water" emulsion, where the ratio of the fatty phase to the aqueous phase ranges from 25:75 to 60:40.

This invention relates to long-shelf-life mousses that do not require storage at low positive temperatures, and to a confectionery product that contains such a mousse as a decorative semi-finished product. The objective of the invention is to obtain a long-shelf-life mousse that provides a mouthfeel similar to traditional chocolate mousses and is superior in consumer characteristics to similar long-shelf-life products currently on the market.

The mousse can be obtained by preparing the fatty and aqueous phases separately, adding the fatty phase to the aqueous phase at a speed that allows for emulsion formation through mixing over a certain period, and then aerating it with a high-speed mixer. In an alternative embodiment, the fatty and aqueous phases can be combined, and the mixture is then aerated.

The authors have developed a functional mousse using fiber and milk thistle seed oil. The whipped dessert product is characterized by increased nutritional value, a balanced chemical composition, and the ability to compensate for deficiencies in vital nutrients [4, 45].

A team of authors from Kiev national university of trade and economics and the O.M. Marzeev Institute of Hygiene and Medical Ecology of the AMS of Ukraine proposed a method for producing a mousse. This method involves preparing the mousse by heat-treating milk, grated chocolate, semolina, powdered sugar, and butter. The mass is then cooled, and a biologically active additive, "Iodoselen," is introduced during whipping. This additive is pre-mixed with vanilla powder. The finished mousse is then poured into molds and cooled for 6 hours. This mousse is distinguished by the addition of the biologically active supplement "Iodoselen" at a concentration of 1.0% by weight of the mousse during the whipping stage. The proposed method allows for the creation of dishes with enhanced taste properties, increased nutritional and biological value, and reduced caloric content [4, 46].

A known method for producing berry mousse from common viburnum and sea buckthorn involves gelatin swelling, dissolving it at a temperature of 40-45°C, mixing it with sugar syrup and a purée-like mass, heating it to 85-90°C, cooling it to 30°C, whipping it, and then allowing it to gel. The proposed mousse differs in that the purée-like mass is obtained by processing the berries in a vortex layer of ferromagnetic particles in a rotating electromagnetic field with a magnetic induction of 0.13 T for 50-55 seconds at a field rotation speed of 3000 rpm, and then separating the seeds by centrifugation [4, 47].

A promising direction for implementing new technologies in mousses is the introduction of biologically active food additives, specifically vitapektin and phytosorbent. Authors note that domestic food additives such as vitapektin and phytosorbent, which are made from natural components like pectin and plantain extract and contain vitamins, antioxidants, and minerals, are promising for the production of a new generation of food products. N.M. Kravchuk and O.V. Shevchenko have developed a technology for producing sweet dishes with the biologically active food additives vitapektin and phytosorbent: "Osoblyvyi" apple mousse with vitapektin and "Osoblyvyi-1" apple mousse with phytosorbent.

The technology for producing these mousses involves thermal processing which aims to maximize the preservation of the vitamin composition of the food additives. The developers conducted a series of studies to determine the quality indicators of the developed mousses. They investigated the content of vitamins, pectin, and mineral substances in the dishes compared to a control group. It was found that the mousses with vitapektin and phytosorbent differed from the control group with an increased content of ascorbic acid, compounds with P-vitamin activity, pectin, and micro- and macroelements vital for the human body [48].

Other developments by the team of authors include a technology for sweet dishes using fruit powders (specifically, a sambuc with the addition of 4.0% apple cryo-powder) and cereal-based smoothies (from millet, oats, flax, wheat bran, and millet with kelp). The conducted research confirms that the developed sweet dishes are characterized by high biological activity, increased content of vitamins, minerals, and dietary fiber, and are recommended for the population's therapeutic and prophylactic nutrition.

The authors have developed a method for producing mousse that involves preparing the raw materials, dosing the components, mixing them, and briquetting them. This method is distinguished by the fact that during the raw material preparation stage, the semolina is pre-treated with infrared radiation at a temperature of 155-165°C, followed by extrusion processing at a temperature of 135-145°C [4].

Researchers have proposed a technology for mousse with improved nutritional value. The development is characterized by an increased content of dietary fiber, vitamins, and minerals. In its composition, the mousse contains plant-based additives such as flaxseed meal, Cystoseira powder, and rosehip syrup. Based on the conducted research, a formulation for a targeted strawberry mousse was developed.

During the study of the organoleptic characteristics of the dishes, a favorable change in the mousse's taste was discovered due to the addition of flaxseed meal. It should also be noted that the introduction of an additive from algae, Cystoseira powder, contributed to maximum iodine, vitamin C, and iron consumption levels.

Using plant-based additives as a source of dietary fiber, vitamins, and microelements is expedient in the technology of gelled sweet dishes with a foam structure. Their inclusion does not deteriorate the organoleptic quality indicators but rather enhances the biological value of the dishes [45].

The author has developed a technology for functional mousses using dried fruits and powder from persimmons, oat flour, and fructose. The scientists substantiated and developed a technology for obtaining powders and dried fruits from persimmons. The drying technology for persimmon fruits ensures the maximum preservation of nutritional components, particularly organic iodine, the content of which after heat treatment is 0,54 mg/100 g [46].

Experimental studies have substantiated the rational concentration for using persimmon powders in model mousse systems. The chemical composition and technological properties of persimmon powders were investigated.

It was established that the organoleptic indicators of the developed sweet dishes are on par with the control group. Analysis of the chemical composition of the mousses indicates that the use of powders and purées from dried fruits improves their vitamin and mineral content.

Researchers propose a mousse formulation in which crushed actinidia berries are used as the primary raw material to ensure better nutritional value and consumer characteristics of the finished product [49].

Actinidia berries are known to be natural concentrates of vitamins A, B, C, P, PP, β-carotene, and minerals. Ripe actinidia berries contain, on average, 500 to 800 mg/100 g of ascorbic acid. This is 10-15 times higher than in lemons and 2-3 times more than in blackcurrants, which are considered a main source of ascorbic acid. Therefore, mousses containing actinidia should become an integral part of the diet.

A key feature of the technological process for producing mousses is the implementation of the principle of component interaction. The regulation of each component's content during blending allows for a finished product with the necessary organoleptic and rheological properties, which is an integral part of modern technological solutions.

The author [47] proposes the development of a mousse composition with pronounced bioprotective properties using mathematical modeling. The basis of the work is the development and optimization of a formulation for producing mousses that includes an additional component to ensure increased nutritional and biological value and expand the assortment of mousses. The goal of the formulation optimization for the new product was to determine the optimal ratio of these components.

The recipe components for the mousse were selected based on their availability, quality, and safety, as well as their high biological indicators: cottage cheese, cream, strawberries, banana, licorice root, gelatin, collagen hydrolysate, and sugar. The collagen hydrolysate content in the mousse recipe was chosen based on dietitians' recommendations. The mousse composition was modeled using MS Excel. Thanks to the introduction of collagen hydrolysate into the recipe, the mousses are characterized by distinct bioprotective properties.

The study of the macronutrient composition of the obtained mousses showed that the finished dishes have a high protein content. The macronutrient content for "Creamy Cottage Cheese Mousse with Bioprotective Action" and "Strawberry Mousse with Bioprotective Action" is 40.76 g and 29.18 g per 100 g, respectively. Based on research into the change in sensory indicators of the developed mousses during storage, it was found that at a temperature of (0±2) °C and a humidity of no more than 65% for 5 days in glass containers, the quality of the mousses maintains high indicators.

In literary sources [50], there is information regarding the use of mango purée as a functional component in mousses. Mango purée was added to the mousse recipe in a quantity ranging from 5,0% to 15,0% of the total mass of the formulation mixture. Cow's milk and soy milk were used as the dairy base. The study showed the expediency of using soy milk in a chocolate mousse composition produced from fermented milk. The use of soy milk also had a positive effect on the organoleptic indicators of the finished mousse.

The results of the scientists' work indicate the possibility of using decoctions of Cetraria islandica (CI) as a biologically active substance for the production of sweet dishes with a foam-like structure, such as mousses, creams, and other dishes (jellies, kissels).

CI (Iceland moss) is characterized by a high carbohydrate content, ranging from 76% to 92%, which are chemically classified as non-digestible polysaccharides. Its use in culinary production is due to its ability to form gels and to enrich the finished product with minerals. It has been established that the relative viscosity of CI decoctions reaches its maximum at a hydromodulus of 1:0,8; at a hydromodulus of 1:0,7, jellies are formed which can be used in culinary products: jellies, kissels, and creams. The authors state that the use of CI made it possible to obtain a mousse with a whipped structure, which is characterized by improved consumer characteristics.

Scientists have proposed a method for obtaining mousse using kappa-carrageenan with qualitatively modified functional-technological properties. This method includes preparing the structure-forming agent, adding it to a fruit or berry decoction, incorporating sugar, pressed juice, citric acid, cooling the mixture, and whipping it until it transforms into a fluffy mass. The gelling agent used is kappa-carrageenan with enhanced functional properties due to the addition of functional additives: sodium tripolyphosphate, calcium citrate, sodium alginate, and calcium chloride [4, 34, 35].

Analysis of information on innovations in the technology of sweet dishes with a foam-like structure has shown that all the aforementioned technological solutions involve either the use of new ingredients in their composition or new technological approaches that ensure stable indicators of the finished product. However, there is a lack of information in the literature regarding the use of starches as structure-forming agents in their composition, which necessitates experimental research.

The proposed approach will allow for the production of mousses with an extended shelf life and will enable their production in both food service establishments and food industry enterprises.

KAPITEL 2 / *CHAPTER 2*
ORGANIZATION, SUBJECTS, MATERIALS, AND METHODS OF RESEARCH

The subjects of this research were:

- aqueous solutions of HPMC D5, HPMC D50, HPMC D4000, E471, E481, and E432 (Tween 20) in a concentration range of 0,1-0,3%;
- suspensions of wheat starch with a starch content of 8.0% and Tween 20 at 0-0,3%;
- model systems of "wheat starch – Tween 20" with a starch content of 2,0-14,0% and Tween 20 at 0,1-0,3%;
- model systems of "wheat starch – Tween 20 – sugar" with a starch content of 8.0%, Tween 20 at 0,25%, and sugar at 0-20,0%;
- model systems of "wheat starch – Tween 20 – citric acid" with a starch content of 8,0%, Tween 20 at 0,25%, and citric acid at 0-1,0%;
- model systems of "wheat starch – Tween 20 – sugar – citric acid" with a starch content of 8,0%, Tween 20 at 0,25%, sugar at 10,0%, and citric acid at 0-1,0%;
- fruit and vegetable mousses using wheat starch.

The quantity of formulation components was determined using a CERTUS electronic balance with a weighing range of 0,01-0,30 kg and a division value of 0,01 kg.

Surfactant solutions were obtained by adding the required amount of surfactant to distilled water at a temperature of 20 ± 2°C, followed by heating.

Suspensions of wheat starch (SWS) were obtained by suspending dry starch in distilled water at 20 ± 2°C. Gelatinized starch dispersions were obtained by heating SWS under specific technological parameters.

Model systems were prepared by mixing wheat starch suspensions with solutions of Tween 20, sugar, and citric acid, followed by heat treatment.

Model systems for determining effective viscosity were prepared as follows: at a temperature of 20°C, the components of the model system were combined with

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distilled water and heated with constant stirring in a water bath to 60°C. The heated systems were transferred to a VPN-0,2 measuring unit, which was pre-set in a thermostat at 60°C. They were left for 5-7 minutes to allow the temperature to stabilize, after which measurements were taken. After the readings were recorded, the thermostat temperature was increased by 5°C, and upon reaching the target temperature, the device readings were recorded again. Heating was performed with stirring.

Model systems for determining foaming capacity and foam stability were prepared as follows: at a temperature of 20°C, the components of the model system were combined with distilled water and heated with constant stirring in a water bath to 60, 70, 80, or 90°C, after which they were whipped for 3 minutes at the corresponding temperature.

The characteristics of the wheat starch are provided in Table 3. The characteristics of the surfactants, supplied by "Appli Chem Gmbh" (Germany), are listed in Table 4.

The raw materials and ingredients used for the production of mousses complied with the requirements of current regulatory documentation: white sugar according to DSTU 4623, citric acid according to DSTU 908, potassium sorbate (E 202), and fruit and vegetable juices and purées according to current regulatory documentation and approved for use by the Central Executive Body for Healthcare.

Table 3 − Characteristics of wheat starch

Indicator name	Actual value
Appearance	White finely dispersed powder
Smell	Inherent, neutral
Moisture, %	13,0
Proteins per CP, %	0,3
Starch on SR, %	97,0
pH value	6,0… 7,0
Ash on CP, %	0,2
Sieve particle analysis > 200 µm, %	2,0
Bulk density, kg/m3	500… 600
NMAFAM, CFU/g no more than	1·104
Mold, CFU/h no more	200
Yeast, CFU/g no more	200
Coliform bacteria in 1 g, Salmonela in 25 g	Not allowed

Table 4 − Characteristics of surfactants

Indicator name	Characteristics of the indicator
E 432 (Twin 20, polyoxyethylenesorbitan monolaurate)	
Appearance	Yellowish, viscous liquid
Density (d20°/4°)	1,095… 1,105
Saponification number	40… 50
Hydroxyl number	100
HPMC (hydroxypropyl methylcellulose)	
Appearance	White powder
Bulk mass, g/ml	0,45… 0,55
Methoxyl group content, %	19,0… 24,0
Hydroxypropyl oxygroup content, %	6,0… 8,5
Ash content, %	≤ 1,0
Humidity, %	≤ 5,0

In the course of experimental studies, fruit and vegetable juices and purees were used, which, in terms of quality and safety, met the requirements of the current regulatory documentation allowed for use by the Central Executive Body in the field of health care.

Materials and raw ingredients used for the production of mousses complied with the requirements of current regulatory documentation: white sugar according to DSTU 4623, citric acid according to DSTU 908, potassium sorbate (E 202) according to current regulatory documentation and permitted for use by the Central Executive Authority in the field of healthcare and with a positive conclusion from the State Sanitary and Epidemiological Service.

Foaming capacity and foam stability were determined by the Lurie method. The foaming capacity (FC, %) was calculated using the formula:

$$FC = \left(\frac{(V_n)}{(V_p)}\right) \cdot 100, \quad (1)$$

where V_p – is the volume of foam, ml;

V_r – is the volume of the solution before whipping, ml.

The foam stability (FS, %) was calculated using the formula:

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$$FS = \left(\frac{(H_n^{15})}{(H_n)}\right) \cdot 100, \quad (2)$$

where H_{n15} – is the height of the foam 15 minutes after whipping, m;

H_n – is the initial height of the foam, m.

The foaming capacity and stability of the model systems were determined by whipping them for 3 minutes and measuring the results obtained immediately after whipping and 15 minutes from the start of whipping.

The surface tension (σ, N/m) of aqueous surfactant solutions was determined using a stalagmometer by the drop counting method. The calculation was performed using the formula:

$$\sigma = \frac{\sigma_0 \cdot n_0}{n} \quad (3)$$

where σ_0, n_0 – are the surface tension and number of drops for distilled water;

n – is the number of drops for the solution being tested.

Dynamic or effective viscosity (η, Pa·s) of samples was determined using a VPN-0.2M constant-stress viscometer. The effective viscosity was determined using the formula:

– $$\eta = k \cdot U \cdot T \cdot A \quad (4)$$

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

The shear rate (γ) was determined using the formula:

$$\dot{\gamma} = \frac{1}{T \cdot A} \quad (5)$$

The obtained data were used to plot flow curves $\eta = f(\dot{\gamma})$.

To determine the viscosity of model systems, viscosity values were compared at the same shear rate, which was chosen in the region of minimum viscosity of the broken structure [11, 14, 15].

The rheological characteristics of CMD during heating were determined on a Brabender amylograph. The initial temperature was 25°C, and the temperature was increased at an interval of 1,5°C per minute. The viscosity of the dispersions was expressed in conditional amylograph units from 0 to 1000.

Energy (enthalpy) changes of CMD were determined by differential scanning calorimetry (DSC). DSC was performed for 8,0% starch suspensions in the temperature range of 20...100°C at an excess pressure of 0,25 MPa and a scanning rate of 1°C/min.

In order to optimize the technological parameters for obtaining mousses using wheat starch, mathematical modeling, particularly correlation-regression analysis, was used.

To describe the dependencies between the output variables and input parameters, an incomplete quadratic model of the form (2.6) was chosen, which makes it possible to experimentally select their optimal combinations.

$$Ai(x, y\ z) = ai_k + ai_k \cdot x + ai_k \cdot y + ai_k \cdot z + ai_k \cdot x^2 + ai_k \cdot y^2$$
$$+ai_k \cdot z^2 + ai_k \cdot x \cdot y + ai_k \cdot x \cdot z + ai_k \cdot y \cdot z \qquad (6)$$

where ai_k – is the coefficients of the mathematical model;

i=1,2 – is the product quality indicator (Y1, Y2);

k – is the coefficients of the mathematical model (k=1...10).

To determine the coefficients of the model, the optimal saturated plan D was chosen, which consists of 10 experiments and does not provide for testing all combinations of input values, as in a full-factorial experiment plan, but is close to it in terms of the accuracy of reproducing the mathematical model (Table 5). The numerical values of the model are presented in a coded form (-1; 0; 1)).

Table 5 − Experiment plan table

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The constructed experimental matrix G, which takes into account the selected type of mathematical model (6) and the determined model coefficients describing the dependence of changes in output indicators on the parameters of the technological process.

The model coefficients were determined using the formula:

$$ai = (G^T \cdot G)^{-1} \cdot G^T \cdot Yi \qquad (7)$$

where Yi – are the vectors that define the quality indicators (i=1,2).

The optimal parameters of the technological process for mousse production were found using programs included in the MathCAD package for solving optimization problems. To objectively judge the degree of reliability of the obtained data, mathematical processing of the research results was carried out.

Microscopy of samples to determine the diameter of air bubbles was performed using a "Biolam" microscope with a ScopeTek DCM-130E 1.3 Mp digital camera, with photographs obtained using the ScopePhoto 3.0 software. The photographs were processed using the open-source software ImageJ 1.47. The resulting dimensional characteristics of the foams were statistically processed using Microsoft Excel software.

Organoleptic analysis of the finished products was conducted using a five-point scale.

The nutritional value of the mousses was determined by the content of proteins, fats, and carbohydrates. The caloric content was determined by calculation.

The chemical composition of the mousses was determined by the following research methods: mass fraction of moisture - by drying samples in a drying oven at a temperature of 130°C, total protein content - by the Kjeldahl method, fat content - by the acid method, carbohydrates - by the ferricyanide method. To determine the ash content, a muffle furnace was used, in which a sample was burned at a temperature of 450-500°C.

Sampling for microbiological studies and their preparation for analysis were carried out in the established order according to the approved methodologies. The content of toxic elements and aflatoxins in the mousses was determined according to the approved methodologies.

The development and refinement of the recipes and technology for mousses using wheat starch were carried out in accordance with the methodological recommendations for the development of recipes for new and signature dishes (products) in restaurant establishments, as well as guided by DSTU 3946 "Food products. General provisions," and the order of the Ministry of Economy of Ukraine № 210 of September 25, 2000, "On the procedure for the development and approval of technological documentation for signature dishes, culinary and flour confectionery products in public catering enterprises."

The general plan of analytical and experimental research is shown in Figure 5.

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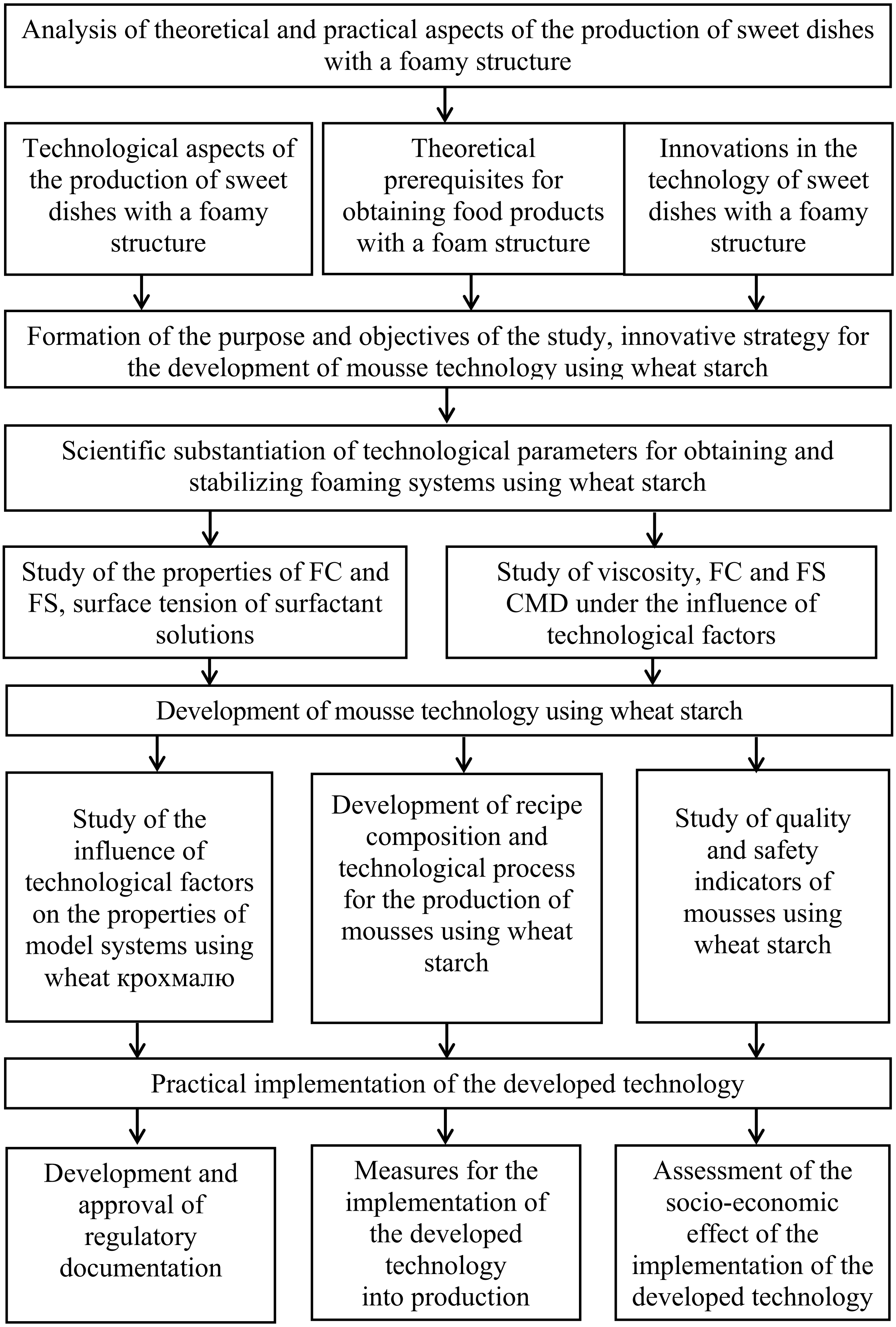

Figure 5 – Plan of analytical and experimental research

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KAPITEL 3 / *CHAPTER 3*
SCIENTIFIC JUSTIFICATION OF TECHNOLOGICAL PARAMETERS FOR OBTAINING AND STABILIZING FOAM-LIKE SYSTEMS USING WHEAT STARCH

An analysis of the current market for sweet dishes offered to consumers by restaurant establishments and food industry enterprises indicates that their assortment, composition, and properties have undergone significant changes, which is primarily due to the intensification of globalization and Ukraine's integration into the world community.

Compliance with world standards can only be achieved by transitioning the industry to an innovative development model and actively implementing modern food production technologies. That is why recently, significant attention has been paid to issues of increasing the efficiency of domestic food enterprises, identifying threats and potential opportunities for industry growth, as well as improving the quality and competitiveness of domestic food products.

Monitoring the assortment of sweet dishes has shown that the products on the market constantly need to be updated in line with modern technological trends and show a "fatigue" effect over time. This results in a failure to fully satisfy consumer needs, which dictates the need to improve technological approaches to their production. The dynamic development of the aforementioned segment determines the feasibility of improving existing technologies and developing new ones.

It should be noted that in the supply chain of sweet dishes to consumers, restaurant establishments are not direct participants in retail trade, as a rule, they do not produce long-storage products due to the lack of scientific and technological principles of production and production management.

Market research indicates that the segment of long-storage whipped dessert products, including those with a foam structure, is not saturated and does not satisfy consumer demand. It is noted that the main principle for filling this niche is a more complete realization of the raw material potential that underlies the industry's functioning. It is also noted that the leader in the production of this group of products is the dairy industry, which offers consumers dairy-based dessert products (cottage cheese, cow's milk, yogurt) with various fillers. It is mainly represented by desserts from brands such as "Dolce," "Chudo," and "President." It is noted that if industrial principles for the production of whipped dessert products were implemented, restaurant establishments would be able to fill the existing segment and provide worthy competition to leading manufacturers.

One of the directions for improving the technology of sweet dishes with a foam-like structure is the use of ingredients in the recipe whose functional and technological properties will ensure the production of final products with stable quality indicators, new consumer properties, and the implementation of a technological process with pronounced industrial production features.

The literature analysis on trends in sweet dish production has shown that existing scientific achievements in the selected segment are not fully realized due to the lack of modern, updated technologies. It has been established that the recipes for many sweet dishes include modified starches, which account for a significant share, hydrocolloids, and surfactants [4, 5, 7, 18, 51]. Starches, whose properties have been changed by physical, chemical, or biochemical influences, act as thickeners and contribute to the formation and stabilization of emulsion systems. However, there is a limited number of culinary product technologies based on the realization of the aforementioned properties. Starches that are characterized by foaming properties and are used in the recipes of sweet dishes with a foam-like structure have not been found in the literature.

Given the above, there is a need to adjust the properties of native starches to use them in the technology of sweet dishes with a foam-like structure, which can be done through the joint interaction of "starch-surfactant."

It should be noted that, as a rule, the formation of a heterogeneous structure of food products with a foam structure differs significantly and opposes the principles of its stabilization. This is achieved by introducing substances into the food system that are characterized by foam-forming and structure-forming properties, such as milk proteins, egg melange, gelatin, and cellulose derivatives, polysaccharides of various

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nature (xanthan, carrageenan, guar gum, etc.). A traditional operation of their production technological process is a sharp change in processing parameters, such as thermal or refrigeration, which leads to the fixation of the foam structure of sweet dishes. But such an approach complicates the technological process both in terms of composition and the length of the technological chain.

Given the above, the technology for the production of sweet dishes with a foam-like structure needs a correction of the technological process, which will allow it to be implemented not only in food production conditions but also to gain widespread use in restaurant establishments.

Taking into account the analytical studies, a working hypothesis was formulated, according to which the controlled regulation of dynamic phase transitions of wheat starch together with surfactants will allow the implementation of mousse technology and the introduction of industrial methods for their production.

The improvement of mousse technology consists of the scientific substantiation of the patterns of obtaining foam systems using wheat starch and low-molecular-weight surfactants and their stabilization, which will allow obtaining a foam-like structure and ensuring its stability over time. The characteristics of the innovative product and the ways of implementing the working hypothesis are shown in Table 6.

Table 6 − Innovative idea of a new product

Characteristic	Indicator description	Implementation methods
Product concept	A ready-to-eat mousse (packaged for retail and restaurant establishments), made with wheat starch and natural fruit and vegetable raw materials. Obtained through a technological process based on starch phase transitions using surfactants. Characterized by high organoleptic indicators typical of mousse.	Achieved through experimental studies using mathematical models.
Product characteristics	Appearance: rectangular or round product. Consistency: foam-like, lush, finely porous, uniform in dispersion throughout the mass,	Achieved by selecting raw materials and ensuring the

Characteristic	Indicator description	Implementation methods
	non-flowing, stable. Color, aroma, taste are well-expressed, characteristic of the initial recipe components, without foreign impurities. Color is typical of fruit or vegetable raw materials. Aroma is pleasant, well-expressed. Taste is moderately sweet.	implementation of the technological process based on starch phase transitions.
Product concept	Ready-to-eat mousse with appropriate organoleptic and physical-chemical indicators. Characterized by stable quality indicators throughout the entire shelf life.	Market research of the whipped dessert products segment
Cost, target segment	Has an average cost that is acceptable for consumers with different income levels.	Economic calculations, selection of components
Packing	It is packed in plastic containers with a capacity of 100... 150 g	Aseptic packaging with a filling machine

Based on the functional properties of substances and their processing methods, the solution to the problem is significantly narrowed, as there are a small number of substances that, while maintaining an affinity for the dispersion medium, would be able to form a new phase.

From this point of view, starch is a unique substance that is a heterogeneous system, since "paste" is a dispersed system characterized by a certain density. Depending on the parameters of the technological process, the specific density of starch paste can be regulated.

The innovative concept of the new product consists of:

– developing the technology for fruit, berry, or vegetable mousses using wheat starch, and involves obtaining a mousse that has certain competitive advantages compared to traditional technology;

– implementing an industrial approach to mousse production.

Within the framework of the formulated working hypothesis, in order to produce mousses by industrial methods, it is necessary to realize dynamic phase transitions of functional substances under the following conditions:

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– the substances involved in the technological process must have pronounced phase transitions to obtain a technological effect (for example, sol-gel transitions for proteins or sol (macromolecular solution)-gel transitions for thermotropic polysaccharides);

– at the first stage of technology implementation, a thermodynamically unstable foam should be obtained, which at the second stage of a continuous technological process will be stabilized by the action of additional mechanical and thermal energy;

– implement the technological process of obtaining a foam-like structure and its fixation in a single-vector thermal flow heating mode [4, 7].

The implementation of this technological task can be achieved by the combined use of surfactants, which are characterized by a high foaming capacity, with wheat starch, which will allow obtaining an unfixed foam system with specified parameters as a stage of a continuous technological process. In addition, the use of wheat starch in the mousse recipe will contribute to the fixation of the foam system by introducing additional mechanical and thermal energy at the production stage.

An important point of the proposed technology is the control of the hydration process of the starch components, which is ensured by using certain temperature values. Under these conditions, the degree of hydration of starch dispersions can be different, i.e., at certain (reduced) temperatures, for example, a 10.0 wt.% starch suspension can show the effect of a 4.0 wt.% starch paste, completely gelatinized. Therefore, the use of certain temperature pauses in the process of starch gelatinization will make it possible to gelatinize the amount of starch that will correspond to its mass concentration for foaming. Under these conditions, it is necessary to carry out the whipping process until a foam structure is formed, and in a single-vector mode, carry out additional heating, which will allow the remaining starch to be gelatinized, achieving the effect of concentration stabilization of the foam to obtain the final product.

Thus, the production of sweet dishes with a foam-like structure using starch can be regulated by changing the properties of the surfaces of the process participants. The formation of additional surfaces in heterogeneous systems requires an increase in the amount of work, which can be realized by introducing surfactants, which occupy a place on the formed surfaces and give the system an additional technological effect. Under these conditions, the technological process is continuous, carried out at high temperatures that reach pasteurization values and allow the production of long-shelf-life products.

Currently, there is a sufficient amount of information in the literature on the use of various surfactants in technologies for sweet dishes with a foam-like structure. Thus, surfactants have become widely used, which have a number of advantages: storage stability, ease of use, and inertness to other ingredients included in the finished product. Surfactants in sweet dish technologies are used mainly to ensure the conditions for the formation of stable foam and structure during their production. The choice of a specific surfactant should be based on its characteristics: hydrophilic-lipophilic balance (HLB) and its functional properties. Numerous literature data indicate that the most common foam-forming agents and foam stabilizers are protein substances, such as egg white and gelatin. The analysis of the recipes for sweet dishes with a foam-like structure showed that cellulose derivatives (HPMC), E471, E481, and Tween 20 (E432) are used as foam-forming agents. The justification for the type and concentration of the surfactant must be carried out taking into account its foaming capacity and the possibility of its implementation in the technological process of mousse production. Based on this, we have chosen six surfactants (Table 7), which are characterized by different HLB values and, accordingly, different foaming capacities and are most often used in the composition of sweet dishes with a foam-like structure.

The scientific interest of the study of the aforementioned surfactants lies in establishing the foaming capacity, foam stability, and surface tension of model "water-surfactant" systems depending on the concentration of the selected substances and the processing temperature. It is necessary to achieve the maximum foaming capacity since its further stabilization will lead to a decrease in the values of this indicator.

The two most important characteristics of foam are its volume and stability. The foam volume depends on the ability of the foaming agent to adsorb at the phase boundary and a rapid decrease in surface tension, as well as the intensity of whipping.

Table 7 − Characteristics of surfactants for obtaining products with a foam-like structure

Name of surfactant	Surfactant characteristics	Permissible level, g/kg
HPMC D5 (hydroxypropyl methylcellulose)	Thickener, emulsifier, stabilizer, gelling agent, dissolves well in cold water	5
HPMC D50 (hydroxypropyl methylcellulose)		5
HPMC 4000 (hydroxypropyl methylcellulose)		5
E 432 / Tween 20 (polyoxyethylene sorbitan monolaurate)	Non-ionic surfactant, dispersible in water, HLB 16.7	3
E471 mono- and diglycerides of fatty acids	Non-ionic surfactant, dispersible in water, HLB 3...4	Not specified
E481 sodium stearoyl-2-lactylate	Ionic surfactant, dispersible in water, HLB 18	5

Foam stability depends on the ability of the foaming agent to form stable interfacial films and a viscous continuous phase. Also, for foam formation, a low value of surface active tension at the liquid-air phase separation boundary is an important indicator. Low surface tension allows for a reduction in the thickness of the medium layer between the bubbles, with the formation of a large separation surface.

During the research, it was established that the model systems "water-E471" and "water-E471" are not capable of foaming in the absence of a fat component. HPMC representatives (D5, D50, D4000) show foaming properties only in the temperature range of 20...60°C, as they are characterized by inverse solubility. Thus, with an increase in the temperature of the "water-HPMC" model systems, their ability to dissolve decreases, as a result of which HPMC precipitates and no foaming occurs. It was established that D50 is characterized by the best FC and FS indicators among the HPMC series (Fig. 6).

It was determined that an increase in the surfactant concentration from 0.1 to 0.5% contributes to an increase in the FC and FS of model systems in the temperature range of 20…60°C. The highest FC value of 450% is characteristic of the HPMC D50 model system at a processing temperature of 40°C, while the highest FS values of 90% are

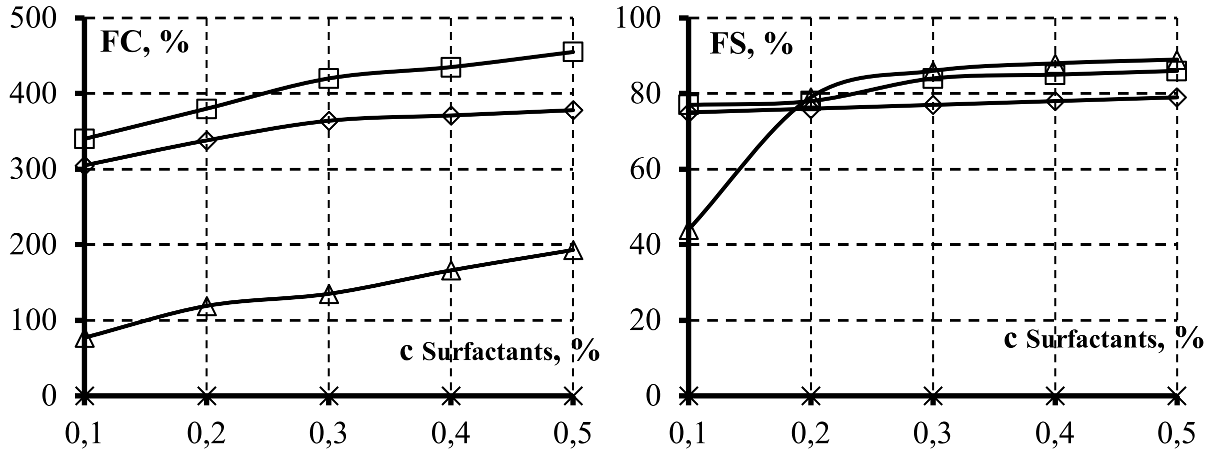

Figure 6 - Foam capacity and foam stability of HPMC D50 depending on concentration at processing temperatures, °C: ◊ – 20; □ – 40; Δ – 60; × – 80.

characteristic of the system at a processing temperature of 60°C. It should be noted that at a temperature of 80°C, the foaming process does not occur due to the precipitation of HPMC.

An analysis of the results obtained confirmed the literature data, which state good indicators of the foaming capacity and foam stability of cellulose derivatives at low positive temperatures. According to the working hypothesis, the technology for producing fruit, berry, or vegetable mousses involves heat treatment of the recipe mixture at a temperature above 60°C (in order to stabilize the foam system), which excludes the possibility of using HPMC as a foaming agent in the composition of the developed mousses.

It was established that an increase in the concentration of E432 (Tween 20) in the system from 0.1 to 0.3% contributes to an increase in the FC and FS indicators in the temperature range of 20...80°C from 375±10% to 430±15% and from 75±5% to 87±5%, respectively (Figure 7) [53].

To confirm the choice of surfactants, their surface tension was studied, as this determines the energy costs for obtaining a heterogeneous dispersed system. The lower the surface and interfacial tension, the easier it is to get a dispersed system. The results of the study on the surface tension of HPMC and Tween 20 solutions (Fig. 7) show that increasing the concentration of surfactants in the system leads to a decrease in the

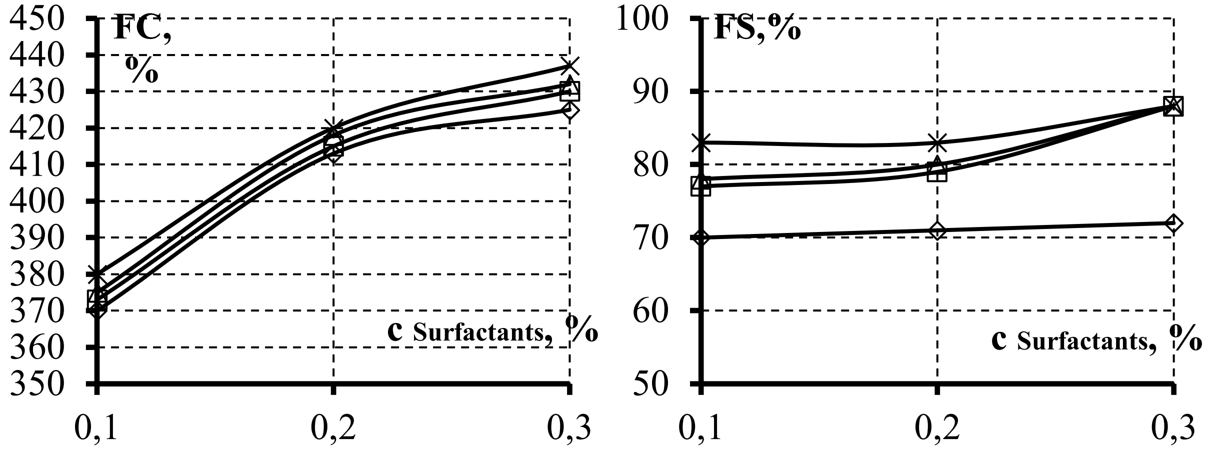

Figure 7 − Foaming capacity and foam stability of Tween 20 depending on concentration at processing temperatures, °C: ◊ – 20; □ – 40; ∆ – 60; × – 80

solutions' surface tension, and thus to an increase in foam stability (Fig. 6). Therefore, the decrease in surface tension, along with the change in surfactant concentration, determines the ability of the solutions to form foams.

The obtained results indicate a direct proportional relationship between the foam capacity and foam stability indicators and the surfactant concentration. According to the literature data, with an increase in the surfactant concentration, the foaming of solutions first increases to a maximum value, then remains practically constant, which is confirmed by the results of the experimental work.

Based on the analysis of the obtained data, it was established that for the values of FC (440%) and FS (89%), the use of the "water-Tween 20" model system in the surfactant range of 0.25...0.3% is rational, which provides FC values at the level of HPMC at 20°C. For further research, model systems with Tween 20 at a concentration of 0.25% were used.

In order to confirm the choice of surfactant, the value of their surface tension was studied, which determines the energy costs for obtaining a heterogeneous dispersed system. The lower the surface and interfacial tensions, the easier it is to obtain a dispersed system. The results of the study of the surface tension of HPMC and Tween 20 solutions (Figure 8) indicate that an increase in the surfactant concentration in the system leads to a decrease in the surface tension of the solutions, and therefore to an increase in the FC indicators (Figure 7). Thus, the decrease in surface tension along with the change in surfactant concentration determines the ability of the solutions to form foams.

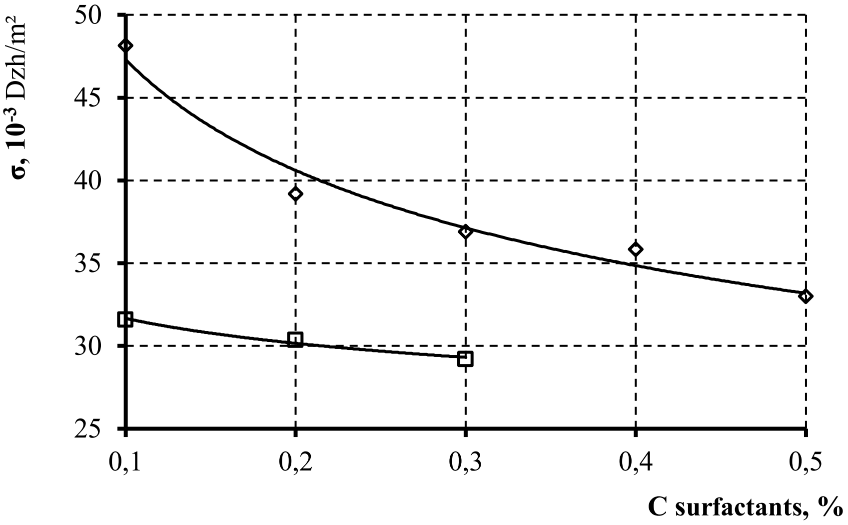

Figure 8 − Dependence of the surface tension of surfactant solutions on concentration, %: ◊ - HPMC; □ - Tween 20.

The obtained data confirm that Tween 20 shows better surface-active properties, as the surface tension of its solutions is 1.3...1.5 times lower than the surface tension of HPMC solutions.

The analysis of the obtained data on determining the indicators of FC, FS, and surface tension of the selected series of surfactants confirmed the feasibility of using Tween 20 in the technology of fruit, berry, and vegetable mousses, the innovative concept of production of which provides for the use of high processing temperatures of the recipe mixture in order to stabilize its structure.

According to the innovative concept, the stabilization of foam-like systems is envisaged due to the use of a structure-forming agent - wheat starch, which, under the influence of thermal and mechanical effects, forms a gelatinized starch dispersion (GSD), which is stable over time. The need to control this process is a mandatory condition for the implementation of the new technology.

GSDs are microheterogeneous systems in which the dispersed phase is swollen starch grains dispersed in a solution of a water-soluble fraction, mainly amylose.

It should be noted that the characteristics of GSDs can change depending on the composition of the food system and the conditions of the technological process

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(temperature, processing duration, concentration of components, their type, etc.).

Literary data indicate [51, 54, 55, 56, 57, 58, 59] that many scientists have dedicated their research to studying the behavior of various types of native starches, specifically the changes in viscosity depending on the processing temperature and the presence of surfactants in the system.

It is known that the nature of gelatinization is influenced by the presence of chemical substances. Some salts are capable of disrupting hydrogen bonds, which promotes the onset of gelatinization, while others inhibit it and act as salting-out agents.

Researchers have noted that surfactants, by adsorbing on the surface of starch granules, can decrease viscosity and swelling capacity. It has been studied the effect of surfactants such as sodium stearoyl-2-lactylate (SSL, anionic surfactant, HLB=10-12), glycerol esters of diacetyl tartaric and fatty acids (DATEM, anionic surfactant, HLB=8...10), glyceryl monostearate (GMS, non-ionic surfactant, HLB=3...4), and distilled glyceryl monostearate (DGMS, non-ionic surfactant, HLB=3...4). They noted that the addition of these surfactants contributes to an increase in the gelatinization temperature and decreases the peak viscosity, but they observed an increase during cooling, especially for SSL.

It was found that the interaction between starch and surfactants depends on the adsorption of surfactants on the surface of starch granules. His further research showed that surfactants form insoluble complexes with amylose. Some surfactants form complexes with amylose and influence the course of the starch gelatinization process. Scientists have noted the ability of some emulsifiers to form complexes with amylose, found that distilled monoglycerides (DMG) have the best complex-forming ability among non-ionic surfactants; sodium stearoyl lactylate (SSL) and calcium stearoyl lactylate were better among ionic ones.

These differences, it turned out, are related to the length of the hydrocarbon chains, their number in the molecules, and the structure of the hydrophilic residues. It has been showed that the ability of monoglycerides to form complexes with amylose depends on the physical form of the surfactant.

It is known that the addition of surfactants contributes to a decrease in the values of maximum viscosity while increasing the initial and maximum gelatinization temperatures. For sucrose esters, this behavior is explained by the formation of an emulsifier-starch compound due to the interaction of hydrophilic groups, which form hydrogen bonds. Esters can also penetrate into the helical structure of amylose and, through hydrophobic bonds, combine into supramolecular structures, reducing the porous structure of amylose. As a result, the dissolution rate of starch increases, and the viscosity decreases.

Thus, the results of many studies indicate that surfactants of different nature interact and affect starch differently during heat treatment. However, no data have been found in the literature regarding the effect of Tween 20 on the properties of wheat starch under the influence of various technological factors.

The effect of Tween 20 on the properties of GSD was determined at a constant shear rate of 320 s^{-1} by plotting the effective viscosity curve. Since the viscosity for GSD is a constant value at this speed, any change in it will be determined by the influence of technological factors.

At the first stage, the effect of Tween 20 (E432) on the viscosity of an 8.0% wheat starch suspension was studied at different processing temperatures (Figure 9).

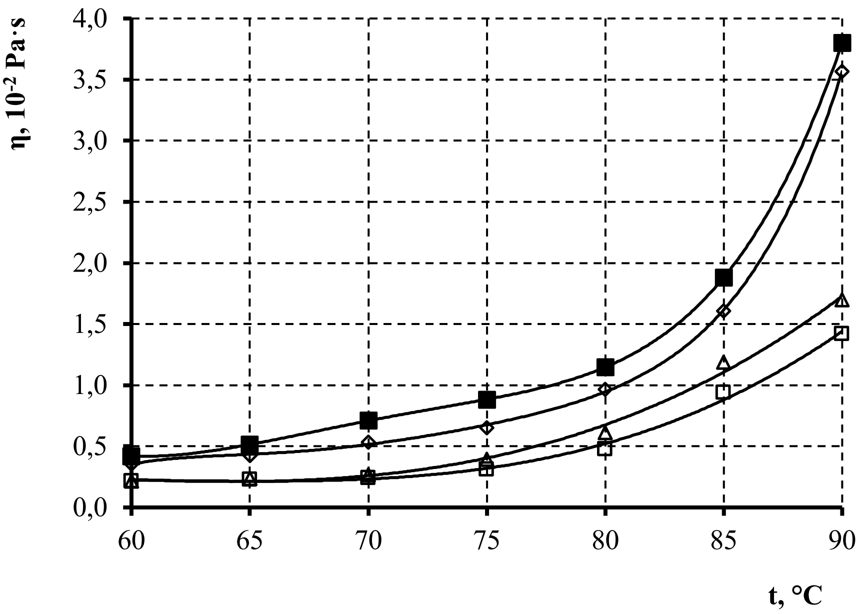

Figure 9 − Changes in the effective viscosity of wheat starch suspensions with processing temperature at Tween 20 concentrations: ■ – 0; ◊ – 0.1; ∆ – 0.2; □ – 0.3

An analysis of the literature data indicates that the gelatinization temperature of wheat starch is in the range of 60°C (initial) to 80°C (final), and the heat treatment temperature, which ensures microbiological purity and stability of food products, is 90±2°C.

It was found that the presence of Tween 20 in the system at concentrations of 0.25...0.3% contributes to a decrease in the viscosity indicators of the starch suspension by 2...2.7 times, and also slows down the start of viscosity growth in the temperature range of 60...70°C, i.e., it increases the gelatinization temperature of wheat starch.

It was found that the viscosity of starch systems with the addition of Tween 20 at concentrations of 0.2% and 0.3% at temperatures of 60...70°C practically does not differ; at a temperature of 90°C, the difference is $0.14 \cdot 10^{-2}$ Pa·s, therefore, for further research, a working concentration of Tween 20 of 0.25% was chosen.

The analysis of the obtained results allows us to state that the presence of a surfactant in the "wheat starch-Tween 20" model system under the influence of temperature contributes to a decrease in the viscosity indicators of the system compared to a starch suspension that does not contain Tween 20. Thus, the modification of starch properties through their joint interaction with surfactants expands the possibilities of their use.

Surfactants, which are introduced into the food system before the start of the starch gelatinization process, penetrate the granules, forming molecular complexes, and reduce the swelling capacity. The degree of influence of complexation with surfactants on the properties of starches during heat treatment varies depending on the type of starch, the type of surfactant, and the processing conditions. For interaction with starch, the surfactant must be well soluble in water or be in a phase state capable of forming monomers.

Before the start of the gelatinization process, the availability of starch molecules is quite limited, so surfactants combine with the surface of the granules and begin to form insoluble starch-emulsifier complexes at the beginning of granule swelling, and amylose begins to dissolve. The resulting insoluble complexes on the surface stabilize the starch granules, as a result of which the rate of further swelling and leaching of

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amylose decreases. The gelatinization temperature increases, as more energy is required for heat treatment or granule swelling. Some surfactants can cover the surface of starch granules with a film, increasing their hydrophobicity and preventing water from penetrating inside.

Thus, it can be assumed that when Tween 20 is added to a starch suspension, it is distributed on the surface of the wheat starch granules (adsorption), which helps to prevent water from penetrating into them and to reduce viscosity indicators. That is, the swelling of starch granules in aqueous systems is inhibited, the consequence of which is a shift of the initial gelatinization temperature towards higher values, which is confirmed by the results of differential scanning calorimetry (DSC) and the Brabender amylograph.

Given that the thermodynamic method, which is DSC, is the most informative and accurate in determining the effect of water on the unpacking of starch granules, we used it to study the process of wheat starch hydration (Figure 10) [52].

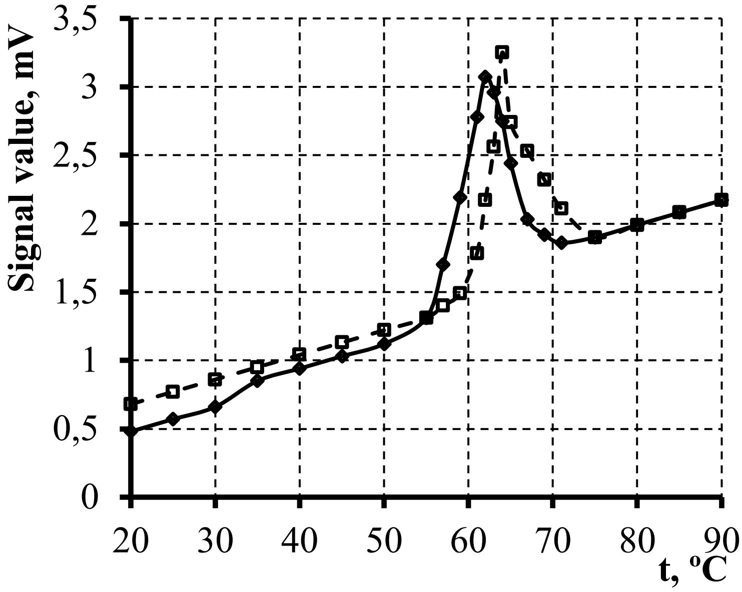

Figure 10 − DSC curves of model systems: ◊ – wheat starch; □ – wheat starch-Tween 20

According to the results of differential scanning calorimetry, it was established that the presence of Tween 20 in the starch suspension contributes to a shift in the temperature range of phase transitions towards higher values: from 55°C for wheat

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starch to 60°C in the presence of the surfactant. The presence of a peak on the DSC curve indicates the occurrence of a phase transition – the melting of the crystalline polymer of starch. On the DSC curve, melting is expressed as an intensive endothermic peak: the beginning of the peak determines the onset melting temperature, and the area of the peak – the enthalpy of melting.

At the beginning of the process, there is a noticeable increase in the mobility of the segments of polymer chains in the amorphous regions. This increase in plasticity or softening of the amorphous glassy matrix, the so-called "glass transition" (transition from a highly elastic state to a glassy state), makes possible even greater penetration of water into the granules, which is accompanied by accelerated swelling of the starch. Further, in the temperature range from 55°C to 75°C, hydrogen bonds, due to the swelling of starch granules, are subjected to stresses and are distributed between the polymer chains in the crystalline phase, and the microcrystallites melt.

Dynamic changes in the viscosity of an 8.0% starch suspension depending on temperature can be recorded using a Brabender amylograph, which characterizes the swelling and gelatinization processes of starch (Figure 11, Table 3.3).

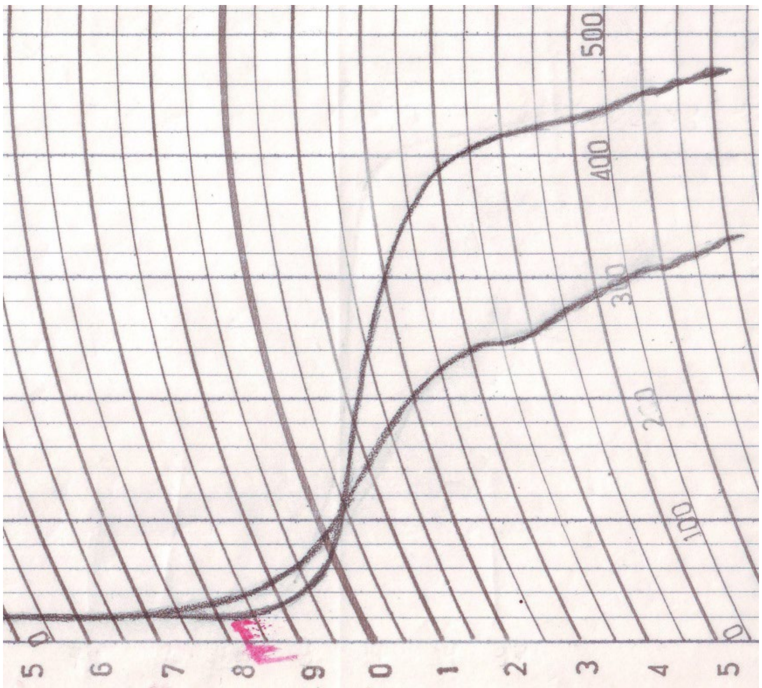

Figure 11 − Amylograms of viscosity changes in model systems: 1 - wheat starch; 2 - wheat starch-Tween 20

Table 8 − Characteristics of model systems

Indicator Name	Model system	
	wheat starch	wheat starch-Tween 20
Gelatinization onset temperature, °C	55	60
Maximum gelatinization temperature, °C	97	97
Maximum viscosity of the suspension, Brab. units	340	470

When the temperature of aqueous starch suspensions rises above 50°C, a partial breakdown of the hydrogen bonds of molecules in the starch granule occurs, which leads to a change in its microstructure. The hydration of amylose and amylopectin increases sharply, and therefore the size of the granules increases - swelling occurs.

As the temperature increases, amylose partially diffuses from the amorphous part of the granule and goes into solution, while amylopectin remains in an insoluble state. During the destruction of the granules, the crystalline part of the granule is destroyed, polysaccharides go into solution, and the gelatinization process begins. The processes of swelling and gelatinization are accompanied by a change in the viscosity of the suspension.

At the beginning of the process, before the gelatinization temperature is reached, adsorptive-capillary or osmotic absorption of moisture by the amorphous regions of the starch granule occurs, its structure is preserved, and the volume increases. At the gelatinization temperature and above, when the intermolecular bonds and the native structure of the granule are destroyed, polysaccharides become soluble and partially go into solution. Under these conditions, the volume of the granules and the viscosity of the system increase significantly.

Heating above the gelatinization onset temperatures contributes to a stronger destruction of the native structure of starch granules. Their layered structure disappears, they increase in volume by several tens of times and turn into bubbles filled with soluble amylose and highly swollen amylopectin. The viscosity of the paste increases, and an intensive release of polysaccharides into the solution occurs. Thus, the paste obtained during the heating of the suspension is a gelatinized swollen granule with dissolved spiral-shaped amylose between them. This system represents a starch sol.

Thus, the gelatinization process of starch is accompanied by the destruction of the structure of the starch granule. One of the signs of gelatinization is a significant increase in the viscosity of the starch suspension. The viscosity of the paste is caused not so much by the presence of swollen starch granules as by the ability of the polysaccharides dissolved in water to form a three-dimensional network that holds a large amount of water. Amylose has this ability most of all, since its molecules are in solution in the form of bent threads, which differ from the conformation of amylopectin spirals. Although amylose accounts for a smaller part of the starch granule, it determines its main properties – the ability to swell and the viscosity of the paste.

The analysis of the data obtained using the amylographic method confirmed the increase in the gelatinization onset temperature of wheat starch in the presence of Tween 20 from 55°C to 60°C.

The next stage is the study of the viscosity of the "wheat starch - Tween 20" model systems depending on the starch concentration at different processing temperatures.

The obtained results (Figure 12) indicate that the processes of swelling and gelatinization of model systems are accompanied by a change in their viscosity and occur differently depending on the temperature. It was found that the viscosity of model systems at a processing temperature of 60°C is linear: the values of viscosity indicators increase from $0.18 \cdot 10^{-2}$ Pa·s to $0.25 \cdot 10^{2}$ Pa·s. At a processing temperature of 70°C, the increase in viscosity indicators in the starch concentration range of 4.0...8.0% is insignificant and amounts to only 1.4 times for 8.0% starch, and for systems with a starch concentration of 12.0%, the viscosity indicators increase by as much as 4 times (from $0.18 \cdot 10^{-2}$ Pa·s to $0.75 \cdot 10^{2}$ Pa·s) [5].

The viscosity curve at 80°C is characterized by an extreme nature, as a 1.4-fold increase in indicators is observed already at a 6.0% starch content in the system, and at a concentration of 12.0%, it reaches 14.4 times. It was found that the viscosity indicator of a 4.0% ($0.22 \cdot 10^{-2}$ Pa·s) gelatinized starch dispersion at 80°C is practically no different from the viscosity indicator of a 12.0% starch dispersion at 60°C and amounts to $0.25 \cdot 10^{-2}$ Pa·s.

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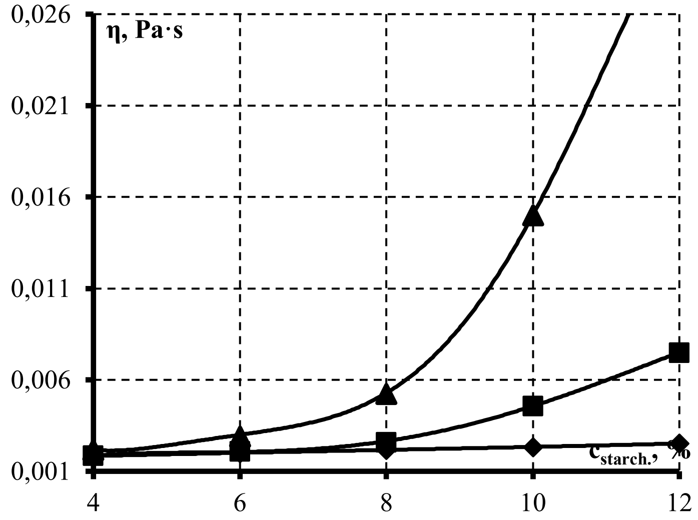

Figure 12 − Dependence of the viscosity of "wheat starch - Tween 20" model systems on starch concentration at processing temperatures: ♦ – 60 °C, ■ – 70 °C, ▲ – 80 °C

It has been experimentally proven that a model system with a wheat starch concentration of 10.0% at a temperature of 60°C (onset of gelatinization) is characterized by viscosity indicators at the level of a 4.0% starch dispersion at a temperature of 80°C (the temperature of complete starch gelatinization), which solves the set technological task and makes it possible to implement the innovative concept.

The practice of scientific research has shown that the formation of a foam structure with an increase in the concentration of the dispersed phase occurs through a series of successive states - from truly liquid (sols) through structured systems to solid-like ones, which have some signs and properties of a solid body [13, 14,15, 16]. The formation and development of spatial foam structures, which are characterized by a certain phase stability, occurs over time by the adhesion or growth of dispersed phase particles and leads in systems with a liquid medium to a change in the nature of flow or to complete solidification. All factors that have a significant impact on this process can be combined into three groups.

The first group includes those related to the presence of a foaming agent, which can be colloidal surfactants or high-molecular-weight compounds.

The second group of factors is related to the properties of the dispersion medium (liquid). Its characteristics are determined by viscosity (the higher the viscosity of the liquid, the more stable the foam), the hydrogen index (pH of the medium), and the presence of low-molecular-weight electrolytes in the liquid.

The third group is related to the influence of external factors. These include temperature, evaporation of liquid from the foam, and mechanical action. With an increase in temperature, the quality of the foam, in most cases, deteriorates, as the desorption of foaming agent molecules increases, the evaporation of liquid from the films increases, and their viscosity decreases. However, for some foams obtained using high-molecular-weight compounds, thermal treatment leads to the transition of the liquid phase into a solid-like one. In this case, a foam is formed that is completely stable.

Another factor influencing the properties of foams is the conversion of a two-phase foam into a three-phase one. The mechanism of stabilization of three-dimensional foams is explained by the narrowing of the Plateau channels. As a result of the decrease in the "free diameter" of the channel, the rate of solution outflow slows down.

To determine the influence of heat treatment parameters on the properties of foam-like systems using wheat starch, the foaming capacity and foam stability of "wheat starch - Tween 20" model systems were studied at different processing temperatures and Tween 20 concentrations (Figures 13...16) [53].

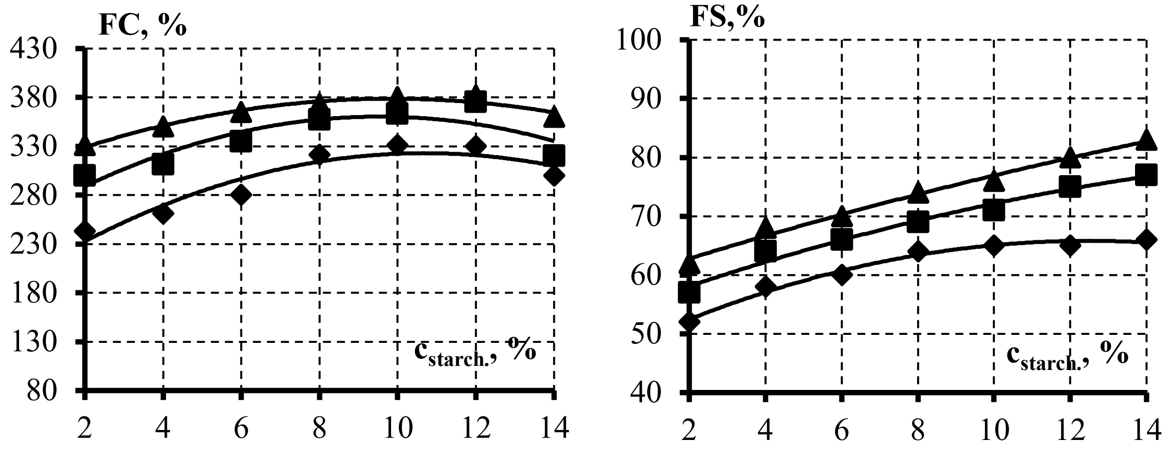

Figure 13 − Foaming capacity and foam stability of Tween 20 at a temperature of 60°C as a function of starch concentration, at a surfactant concentration, %: ♦ – 0.1; ■ – 0.2; ▲ - 0.3.

It was established that at a processing temperature of 60°C (Figure 13), an increase in the values of foaming capacity (FC) and foam stability (FS) of the model systems is observed depending on the Tween 20 concentration. The highest FC values are characteristic of systems containing 6.0...12.0% starch and 0.3% surfactant, and are within the range of 365...380%. The highest FS value (83,0%) is characteristic of the system with a Tween-20 concentration of 0.3% at a maximum starch content of 14.0%.

It was determined that at a processing temperature of 70°C, a decrease in FC values and an increase in FS values are observed (Figure 14) [53]. The best FC is characteristic of the "wheat starch - Tween 20" model system with a starch concentration of 6,0%, the value of which is 370.0% at a surfactant concentration of 0,3%. The highest FS value is observed for the model system with a surfactant concentration of 0.3% and a starch concentration of 12,0%, the value of which is at the level of 95,0%.

It was established that at a processing temperature of 80°C (Figure 15) [53], a decrease in FC values and an increase in FS values are observed due to the starch gelatinization process.

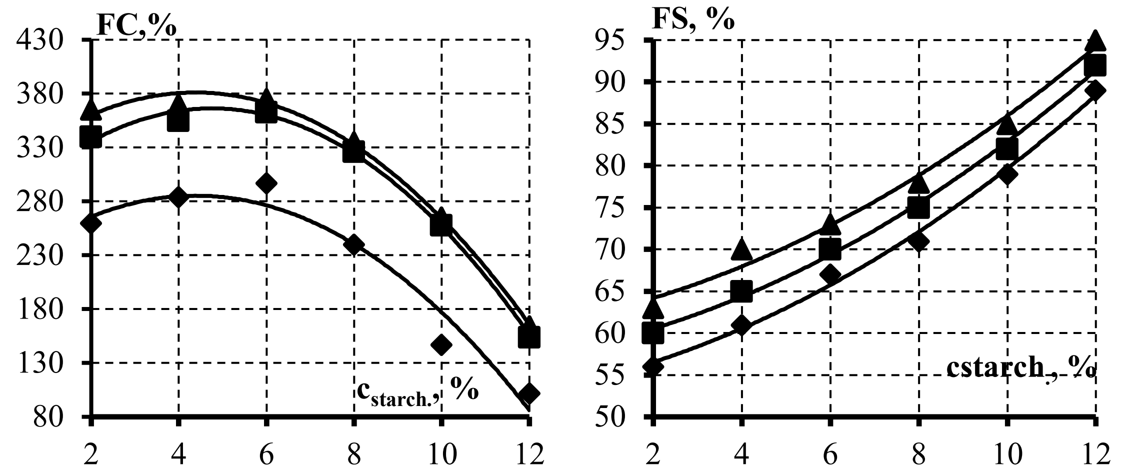

Figure 14 − Foaming capacity and foam stability of Tween 20 at a temperature of 70°C as a function of starch concentration at a surfactant concentration, %: ♦ – 0.1; ■ – 0.2; ▲ - 0.3.

The best foaming capacity indicators are characteristic of systems with a starch concentration in the range of 4.0...6.0% at a surfactant concentration of 0.3%, with values at the level of 380...325%. The highest foam stability value is characteristic of systems with a surfactant concentration of 0.3%, which, depending on the starch concentration in the system (2.0...10.0%), is in the range of 75...100%.

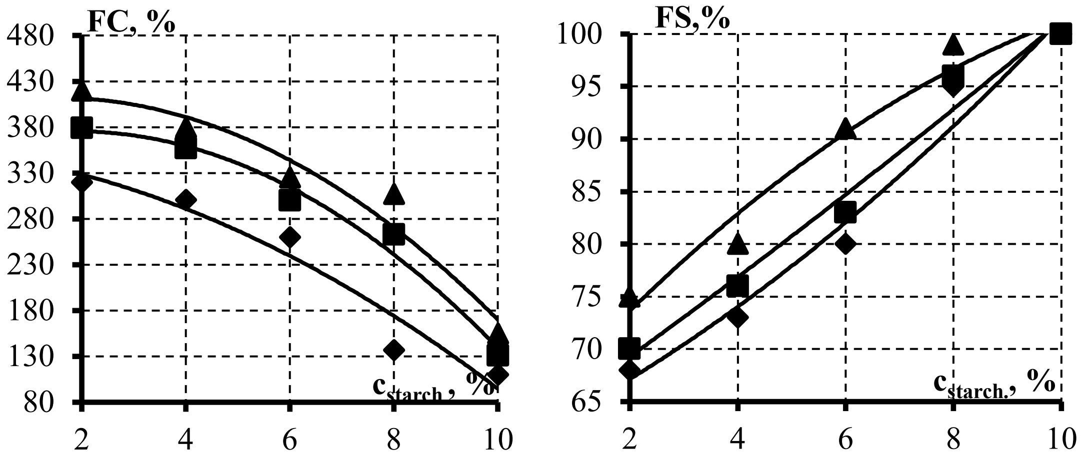

Figure 15 − Foaming capacity and foam stability of Tween 20 at a temperature of 80°C as a function of starch concentration at a surfactant concentration, %: ♦ – 0.1; ■ – 0.2; ▲ - 0.3.

An analysis of the obtained data (Figure 16) [53] allows us to state that an increase in the processing temperature of the model systems contributes to an increase in their viscosity, which, in turn, leads to a decrease in foaming capacity but an increase in foam stability.

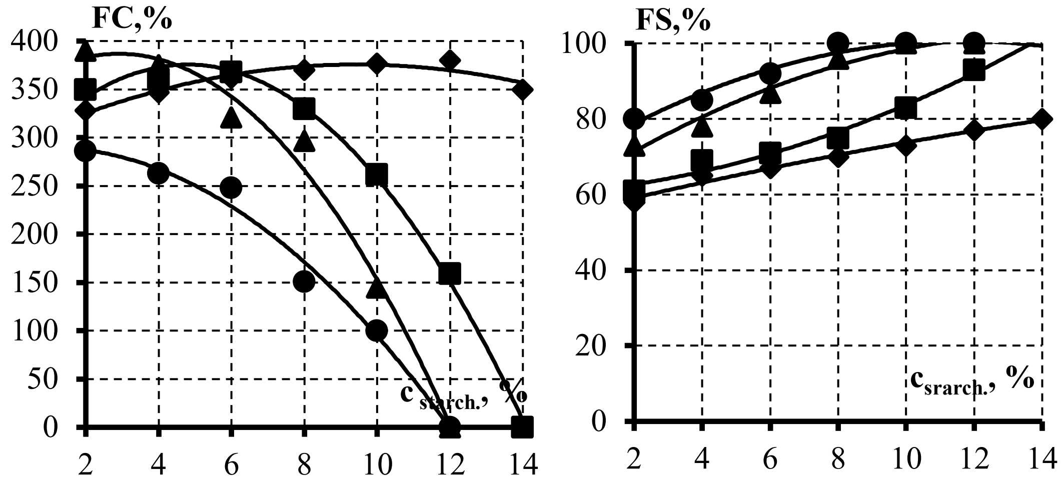

Figure 16 − Foaming capacity and foam stability of the "wheat starch - Tween 20 (0.25%)" model systems as a function of starch concentration at processing temperatures, °C: ♦ – 60; ■ – 70; ▲ – 80; ● – 90.

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It was found that at a processing temperature of 60°C, i.e., at the beginning of the gelatinization process, when there is no significant increase in viscosity with an increase in the starch concentration in the system, the highest FC indicators are observed at the level of 330-380%, while the FS indicators are 60-80%. This can be explained by colloidal instability, since the system is dominated by starch granules that are not able to maintain the structure, but rather contribute to its destruction [53].

Foam stability, with indicators close to 100%, is characteristic of systems containing 8.0-14.0% starch at processing temperatures of 80, 90°C and 12.0% starch at a processing temperature of 70°C. The foaming capacity for systems with a starch concentration of 6.0% is 250-285%, for 8.0% starch - 160-250%. Model systems with a starch concentration of 12.0% did not form foam at processing temperatures of 80, 90°C, and at 70°C, the FC indicators were characterized at the level of 160%, which is insufficient for the implementation of mousse technology using wheat starch.

The analysis of the obtained data allows us to state that an increase in the wheat starch concentration leads to an increase in the FS indicators. This is explained by the phase transitions of starch together with the surfactant (Tween 20), which allows obtaining model systems that are stable over time.

Based on the analysis of experimental studies, a schematic diagram for the production of fruit and vegetable mousses has been developed (Figure 17), which provides for combining the recipe components and heating them together at a temperature of 60±2°C with stirring, followed by whipping the recipe mixture at a temperature of 60-65°C with a gradual increase to 85±2°C.

In order to ensure microbiological indicators at the normative level, pasteurization at a temperature of 95±2°C will ensure the stability of the obtained foam-like system.

According to the proposed scheme, wheat starch together with Tween 20 act as a foaming agent and a stabilizer of the system. This is possible due to the unique property of starch to form colloidal dispersions (paste) during hydrothermal treatment. In essence, the formation of paste is a forced hydration of the starch components, which is achieved by using certain temperature values. Under these conditions, the degree of hydration of starch dispersions is different, i.e., at low temperatures (60-65°C), a 10.0%

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starch dispersion is characterized by indicators at the level of 4.0%, which allows the innovative concept to be implemented.

It was found that using temperature pauses during starch gelatinization will make it possible to gelatinize the amount of wheat starch that will not interfere with the foaming process, and under these conditions, to carry out whipping, which will ensure the whipped structure of the mousse. In order to stabilize the foam system in a single-vector mode, additional heating to 85±2°C should be carried out, which will lead to the gelatinization of the rest of the starch, achieving the effect of concentration stabilization of the foam to obtain the final product.

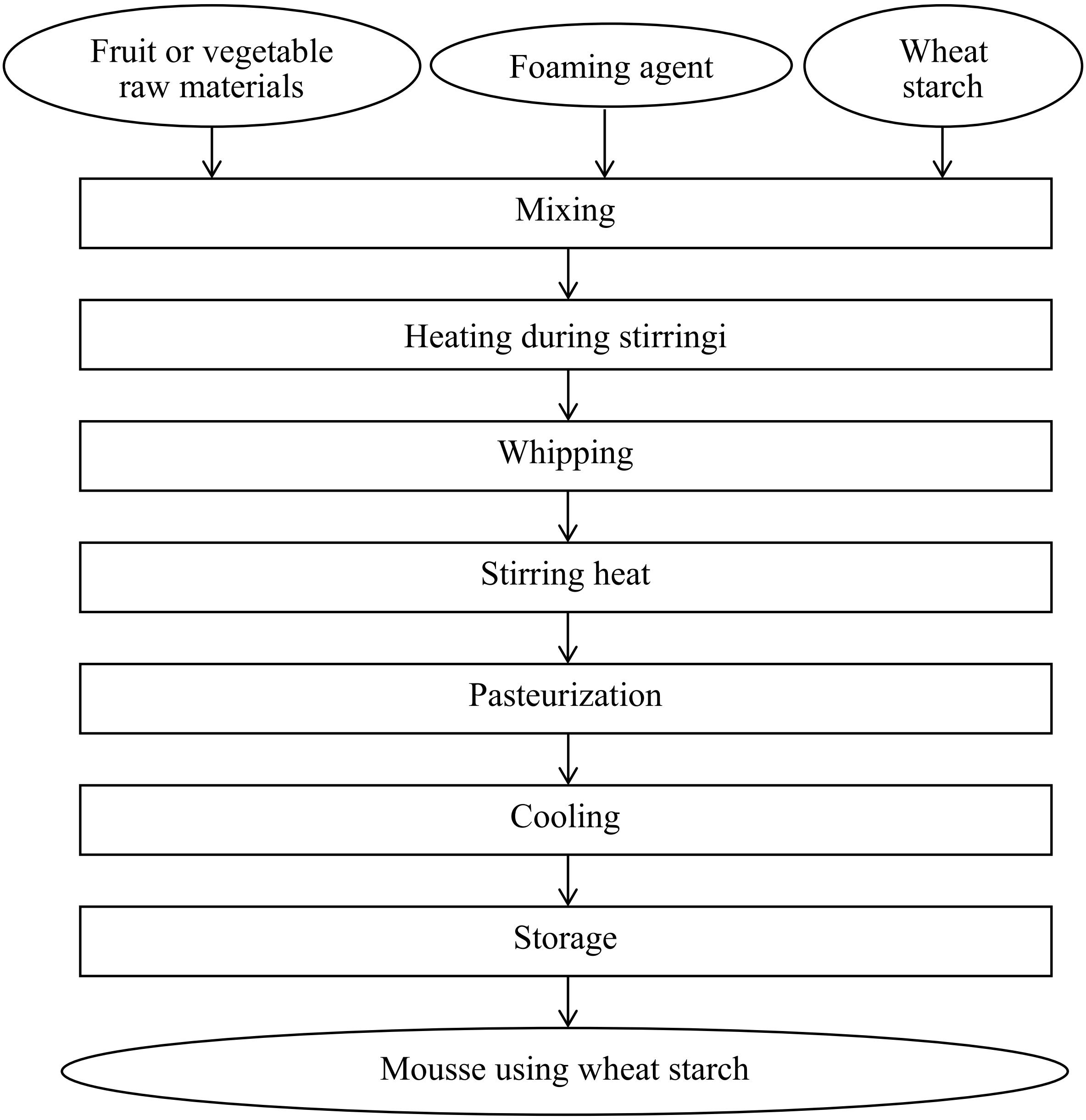

Figure 17 − Schematic technological diagram for mousse production using wheat starch.

Under these conditions, the technological process is continuous, carried out at high temperatures that reach pasteurization levels, and allows for the production of food with a long shelf life [5].

Determining the technological parameters for obtaining mousses with wheat starch, which must meet the specified quality indicators, is a complex technological task, the solution of which is based on the use of modern methods of experimental design theory with mathematical modeling.

Through experimental studies, the main dependencies between the input technological parameters for obtaining mousses and the values of the output variables (mousse quality indicators) were established, which provide an understanding of the existence of objective relationships between the input and output parameters. Based on the obtained mathematical model, using the methods of numerical analysis, multi-criteria optimization, and experimental optimization, the values of the technological parameters for obtaining mousses that best correspond to the specified quality indicators were established.

The purpose of building a mathematical model is to find the corresponding dependencies between the input and output parameters of the technological process. Based on the results of the research, the following were chosen as the input variables of the technological process for obtaining mousses: x – wheat starch concentration, %; y – whipping temperature, ºC; z – surfactant concentration, %; and as the output variables (quality indicators): Y1 – foaming capacity, %; Y2 – foam stability, % [59].

As a result of mathematical calculations, two mathematical models were obtained for each quality indicator:

$$A1(x, y\, z) = a1_1 + a1_2 \cdot x + a1_3 \cdot y + a1_4 \cdot z + a1_5 \cdot x^2 + a1_6 \cdot y^2 + a1_7 \cdot z^2 + a1_8 \cdot x \cdot y + a1_9 \cdot x \cdot z + a1_{10} \cdot y \cdot z \qquad (8)$$

$$A2(x, y\, z) = a2_1 + a2_2 \cdot x + a2_3 \cdot y + a2_4 \cdot z + a2_5 \cdot x^2 + a2_6 \cdot y^2 + a2_7 \cdot z^2 + a2_8 \cdot x \cdot y + a2_9 \cdot x \cdot z + a2_{10} \cdot y \cdot z \qquad (9)$$

Checking the models for adequacy using statistical criteria showed that they accurately reproduce the experimental results and can be used for further research, that is, foaming capacity and foam stability can be described by the corresponding relationships, where the input process parameters are used as variables.

To find the set of input variables that determine the maximum quality indicators of mousses, the function was used $P = Maximize\ (A, x, y, z)$. The determined quality indicators are realized for different combinations of technological parameters. The maximum approximation to the specified values for a certain criterion was carried out using multi-criteria optimization methods. The overall choice of the best product quality criterion is due to the specifics of the technological task. In this case, the least squares criterion q was chosen, which is described by the formula:

$$q = (y_i - y_{iз})^2 \quad (10)$$

where y_i – a quality indicator, the value of which is determined by the results of the mathematical model calculation;

$y_{iз}$ – a given (required) quality indicator of the corresponding parameter.

To solve the stated problem, taking into account the q criterion, it is necessary to "fold" the quality indicators into a single complex criterion.

The general problem statement is presented in the form of 11, which consists in the simultaneous minimization of two criteria of quality indicators with respect to the technological parameters for obtaining mousses using wheat starch:

$$q_i(X) \to \min_{X \in \Omega}, i = 1 \dots 3 \quad (11)$$

where q(X) – the general quality criterion;

Ω – the set of allowed solutions for using criteria (all possible combinations of mousse input indicators).

The choice of the general quality criterion is determined by the values of the output quality indicators of the mousse production technological process after conducting the experiment. The analysis of the obtained results showed that all output data have the same order. Therefore, the following expression, which meets the requirements of the least squares method, was chosen as the approximation criterion that allows all criteria to be "folded" into one:

$$C(X) = \sum_{i=2}^{2} [q_i(X) - W_i]^2 \quad (12)$$

wher $q_i(X)$ – the value of the i-th indicator, calculated by the mathematical model;

W_i – the required value of the quality indicator regarding the requirements for this technological process, which was determined through previous research.

The final formula for finding the parameters of the technological process X, which is used in the standard Minimize program of the MathCAD package, is as follows:

$$C = Minimize(q, X) \tag{13}$$

де C – the vector of technological process parameters that ensure implementation;

X – the vector of the input process variables, which consists of the variables (x,y,z).

Graphical interpretations of the mathematical models for the foaming capacity and foam stability indicators at a temperature of 60 °C are shown in Figures 18-20 [59].

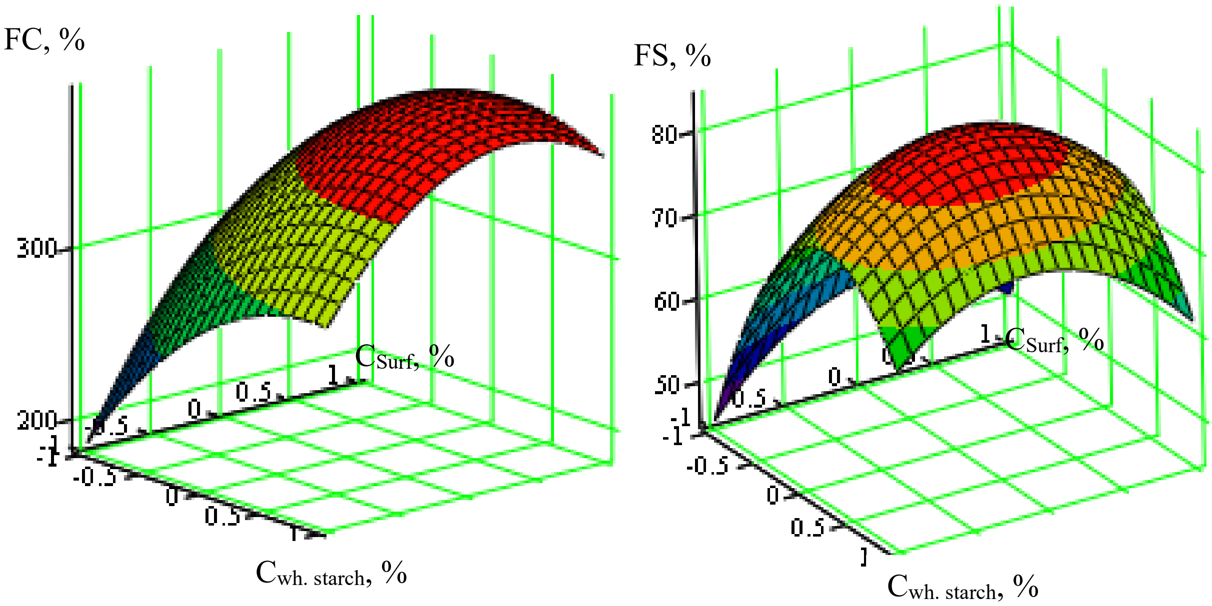

Figure 18 − Response surfaces of mathematical models for the foaming capacity and foam stability of mousses using wheat starch at a temperature of 60 °C.

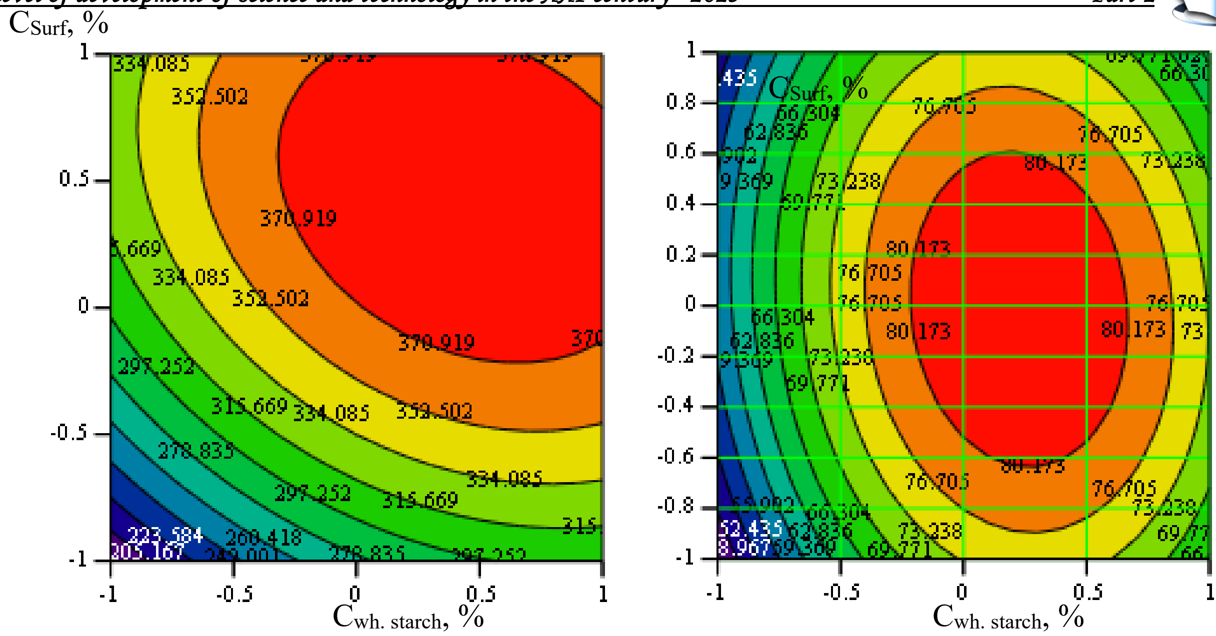

Figure 19 − Maximum values of foaming capacity (C1) and foam stability (C2) of mousses using wheat starch at a temperature of 60 ºC.

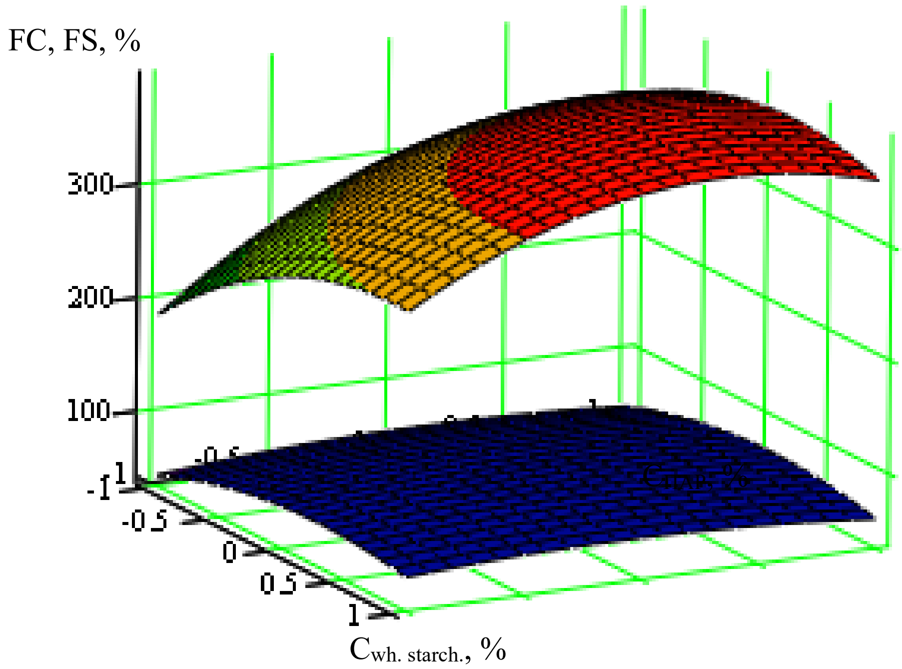

Figure 20 − Graphical interpretations of mathematical models for the foaming capacity and foam stability of mousses using wheat starch at a temperature of 60 ºC.

The final data, presented in a coded form, calculated using the mathematical model and by using the multi-criteria optimization method, have the following values:

x=0.377; y=-1; z=0.37. After converting to natural values, we get the following values: x=10.262%; y=60 ºC; z=0.237%. In this case, the values of the quality indicators of mousses using wheat starch are: У1=388.875%; У2=81.787%, which corresponds to the set task [59].

Thus, the optimization results show that the optimal starch concentration is 10.3%, the surfactant concentration is 0.24%, and the processing temperature is 60°C. With these parameters, the foaming capacity value is 388.9%, and the foam stability is 81.8%, which allows for the implementation of the proposed innovative strategy for developing mousse technology using wheat starch.

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KAPITEL 4 / *CHAPTER 4*
DEVELOPMENT OF MOUSSE TECHNOLOGY USING WHEAT STARCH

The results of experimental studies allowed us to substantiate the type and concentration of the surfactant, the content of the main recipe components (wheat starch and fruit/berry raw materials), and the processing temperature of the model systems that ensure high foaming capacity and foam stability, and allowed us to develop a schematic diagram for mousse production.

The production of fruit and vegetable mousses using wheat starch requires substantiating the parameters of their production process, studying the influence of technological factors on the foaming capacity and foam stability of the mousses, substantiating and developing the recipe composition and production process, and evaluating quality indicators.

To obtain high-quality mousses using wheat starch, it is necessary to consider the influence of recipe components and the parameters of the production process and to determine their rational parameters.

To substantiate and develop mousse technology, it is necessary to transition from model to real systems, and understanding the mechanisms of the influence of recipe components (sugar, citric acid) on the starch gelatinization processes is the basis for substantiating the recipe and parameters of the mousse production process using wheat starch.

In order to obtain mousses with stable consumer characteristics, the influence of technological factors on the viscosity of the "wheat starch - Tween 20" system was studied.

It is known that the course of the starch gelatinization process and its viscosity indicators depend not only on the processing temperature and the type of starch, but also on the type and content of other components. This must be taken into account, since in the process of food production, starch is present in the presence of substances such as sugar, proteins, fats, food acids, mineral salts, surfactants, and water.

In food products, water is not just a medium for reactions, but an active component

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in the processes that occur, and what matters is not the amount of water, but its availability to participate in transformations or its activity. Water activity is affected by salts, sugars, and other components that bind water. Therefore, if these substances are present in large quantities, the water activity will be lower, and starch gelatinization may not occur or occur to a limited extent.

For example, sucrose at a concentration of up to 20.0% increases the gelatinization temperature of starches and increases the viscosity of pastes, while sodium chloride, even in very small concentrations, decreases it. A high sugar content slows down the rate of starch gelatinization and lowers the peak viscosity. Disaccharides are more effective in slowing down the gelatinization process and lowering the peak viscosity than monosaccharides. In addition, sugars reduce the strength of starch gels, acting as plasticizers and interfering with the formation of binding zones.

The effect of sugar on the course of gelatinization and the properties of GSD is of practical importance in the production of mousses. It is known that sucrose delays the swelling of starch granules in water due to its high content of dry matter. Therefore, for a comprehensive substantiation of the use of wheat starch in mousse technology, we consider it necessary to study the effect of sugar on the viscosity indicators of the "wheat starch-Tween 20" model system.

Literature data indicate that the sugar concentration in sweet dishes varies from 5.0 to 20.0%, which ensures good consumer characteristics. It is known that sugar has a structure-forming ability, which is based on the property of sucrose solutions to gradually change the viscosity of the system with a change in temperature, while not changing the phase state. The addition of sucrose and other sugars to starch-based systems increases the gelatinization temperature and makes it difficult for starch granules to swell, and at a high sugar concentration, the granules swell poorly at all. In the case of wheat starch, the addition of sugar leads to a decrease in water activity, which leads to an increase in the gelatinization temperature.

Thus, when sugar was added to the "wheat starch-Tween 20" model system in the temperature range of 65-70°C, an increase in viscosity indicators of 2-2.3 times was observed at a content of 5.0 and 10.0%, and 3.4 times at a content of 20.0% sugar (Figure 21). The viscosity indicators were (0.23-0.3)·10⁻² Pa·s at a temperature of 65°C and (0.52-0.59)·10⁻² Pa·s and (0.87±0.04)·10⁻² Pa·s at a temperature of 70°C, respectively. It should be noted that a sharp increase in viscosity indicators was observed in the temperature range of 85-90°C [60].

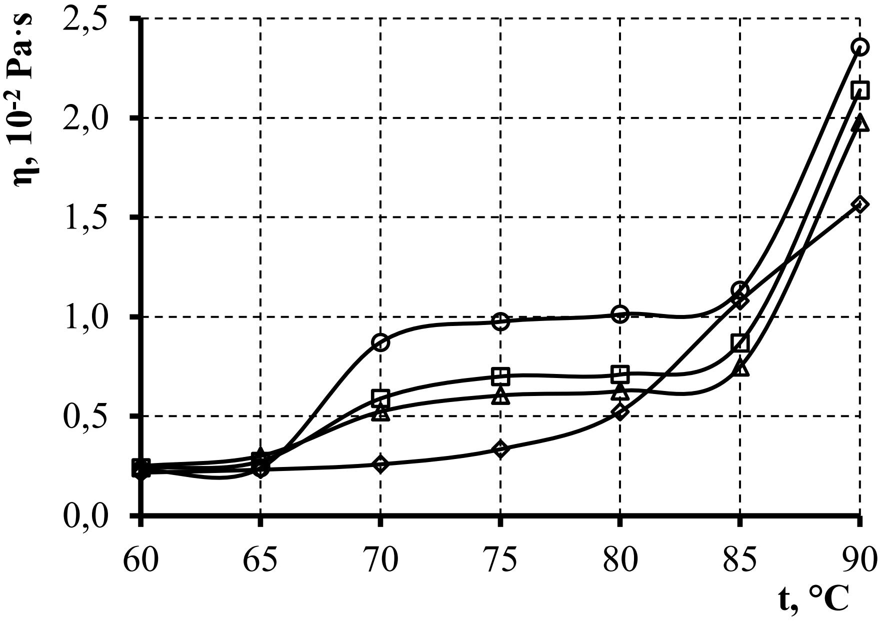

Figure 21 − Changes in the effective viscosity of the "wheat starch - Tween 20" model systems with processing temperature at sugar concentrations, %: ◊ – 0; Δ– 5.0; □ – 10.0; ○ – 20.0.

The obtained results indicate that the regularities established by scientists regarding the effect of sugar on a starch suspension during heat treatment, such as an increase in gelatinization temperature and an increase in maximum viscosity, are also characteristic of the "wheat starch-Tween 20" system. At a sugar content of 20.0%, the highest indicators of effective viscosity were observed starting from 66°C (at a temperature of 70°C, the viscosity was (0.87±0.04)·10⁻² Pa·s, and at 90°C - (2.4±0.12)·10⁻² Pa·s, whereas the viscosity of the system without sugar was (0.26±0.01)·10⁻² and (1.6±0.08)·10⁻² Pa·s, respectively). Apparently, at the beginning of the gelatinization process, sucrose slows down the swelling of starch granules in the aqueous suspension due to an increase in the dry matter content in the system, which

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restrains the onset of viscosity growth in the temperature range of 60-65°C.

Studies of the behavior of the "wheat starch - Tween 20" model systems in the presence of sugar on a Brabender amylograph showed similar regularities of changes in effective viscosity (Figure 22).

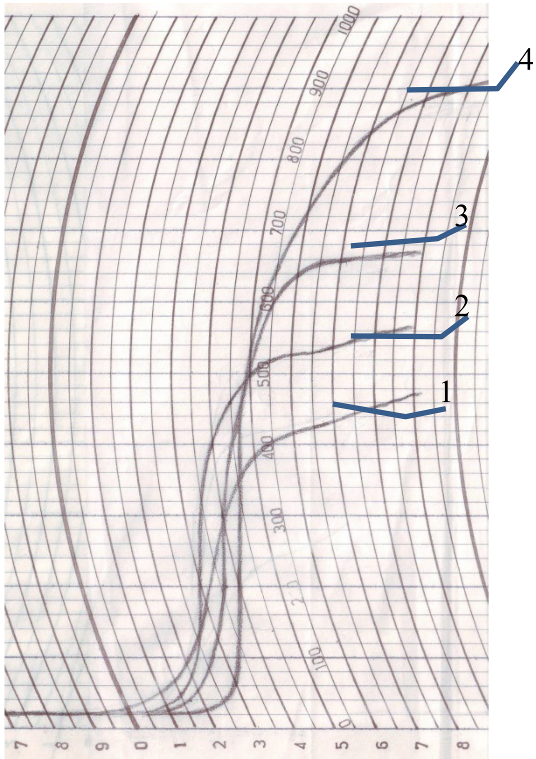

Figure 22 − Amylograms of viscosity changes in the "wheat starch - Tween 20" model systems at sugar concentrations, %: 1 - 0; 2 - 5.0; 3 - 10.0; 4 - 20.0.

The addition of sugar to the "wheat starch - Tween 20" systems slows down the onset of the gelatinization process by (1-3)·60 s, i.e., by 1.5-4.5°C, and thus contributes to an increase in its initial temperature. When the sugar concentration in the system increases, the swelling of starch granules at the beginning of heating occurs slowly, and after reaching a temperature that promotes the penetration of water into the granule and its unpacking, the process occurs more intensively, thereby increasing the value of the maximum viscosity peak: at a sugar concentration of 5.0-10.0%, the viscosity increases by 1.3-1.5 times, and at 20.0% - by 2.1 times compared to systems without sugar.

Thus, it was established that the addition of sugar to the "wheat starch - Tween

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20" model systems at the beginning of the gelatinization process will slow down the increase in viscosity, and at the final stage will contribute to the fixation of the structure due to the increase in viscosity and will prevent the destruction of the foam through the flow of liquid through the Plateau channels.

Based on the viscosity indicators and organoleptic characteristics of the developed products, the most acceptable sugar concentration in the system was chosen as 10.0%. It is known from the literature that the course of the starch gelatinization process depends on the pH values: even a small change in acidity can lead to strongly pronounced changes in the process of GSD formation.

Since fruit and berry or vegetable raw materials, which are characterized by certain pH values, are used in mousse recipes, a food system was modeled in which the properties of these raw materials were performed by citric acid. The content of citric acid was varied in the range of 0-1.0%, which was chosen in terms of the pH of the fruit and berry raw materials, which are provided for in the recipe composition of mousses (Figure 23) [60].

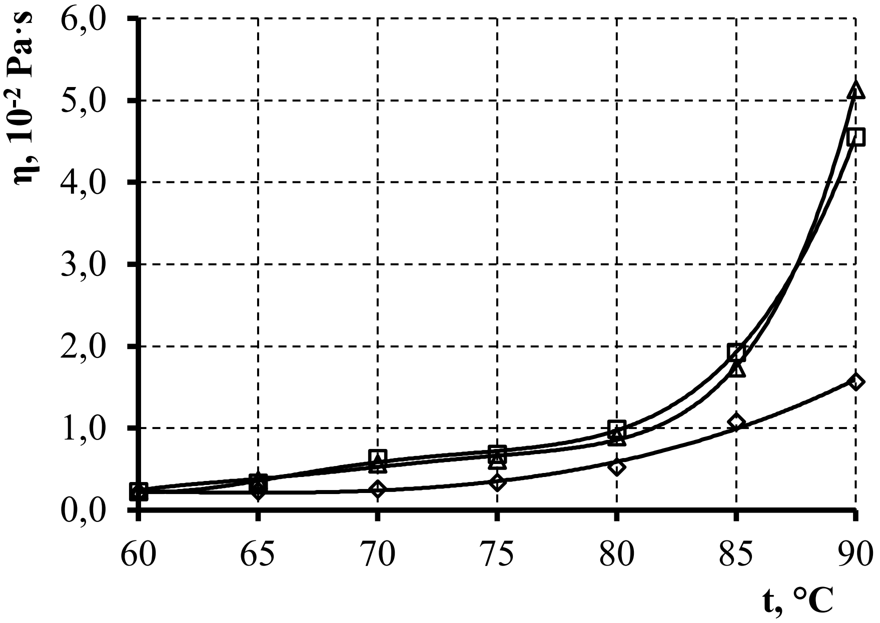

Figure 23 − Amylograms of viscosity changes in the "wheat starch - Tween 20" model systems at sugar concentrations, %: 1 – 0; 2 – 5.0; 3 – 10.0; 4 – 20.0.

The addition of sugar to the "wheat starch – Tween 20" systems slows down the

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onset of the gelatinization process by (1-3)·60 s, i.e., by 1.5–4.5°C, thus contributing to an increase in its initial temperature. When the sugar concentration in the system increases, the swelling of starch granules at the beginning of heating occurs slowly, and after reaching a temperature that promotes the penetration of water into the granule and its unpacking, the process becomes more intense, thereby increasing the value of the maximum viscosity peak: at a sugar concentration of 5.0-10.0%, the viscosity increases by 1.3-1.5 times, and at 20.0% – by 2.1 times compared to systems without sugar.

Thus, it was established that the addition of sugar to the "wheat starch – Tween 20" model systems at the beginning of the gelatinization process will slow down the growth of viscosity, and at the final stage will contribute to the fixation of the structure due to the increase in viscosity and will prevent foam destruction through liquid drainage along the Plateau channels.

Based on the viscosity indicators and organoleptic characteristics of the developed products, a sugar concentration of 10.0% was chosen as the most acceptable in the system. It is known from the literature that the course of the starch gelatinization process depends on pH values: even a small change in acidity can lead to pronounced changes in the process of GSD formation.

Since mousse recipes use fruit, berry, or vegetable raw materials, which are characterized by certain pH values, a food system was modeled in which the properties of these raw materials were represented by citric acid. The content of citric acid was varied in the range of 0–1.0%, which was chosen in terms of the pH of the fruit and berry raw materials intended for the mousse recipe (Figure 4.3). Figure 4.3. Changes in the effective viscosity of the "wheat starch – Tween 20" model systems with processing temperature at citric acid concentrations, %: ◊ – 0; Δ – 0.5; □ – 1.0.

The results for determining the effective viscosity of the "wheat starch–Tween 20" model systems in the presence of citric acid showed a slight increase in indicators, which was already observed at a temperature of 65±2°C.

Thus, at 70°C, the values doubled, maintaining this trend up to 85±2°C. At a temperature of 90°C, the model system with an acid concentration of 0.5% was characterized by the highest viscosity, with a value of (5.1±0.25)·10⁻² Pa·s, while the viscosity value of the system without acid was (1,6±0,08)·10⁻² Pa·s.

Amylographic studies of the behavior of the "wheat starch–Tween 20" model systems under the influence of citric acid (Figure 24) found that the gelatinization process in these systems begins earlier and is more intense with a significant increase in viscosity in the presence of acid, but after reaching the hydrolysis temperature, the viscosity begins to decrease rapidly.

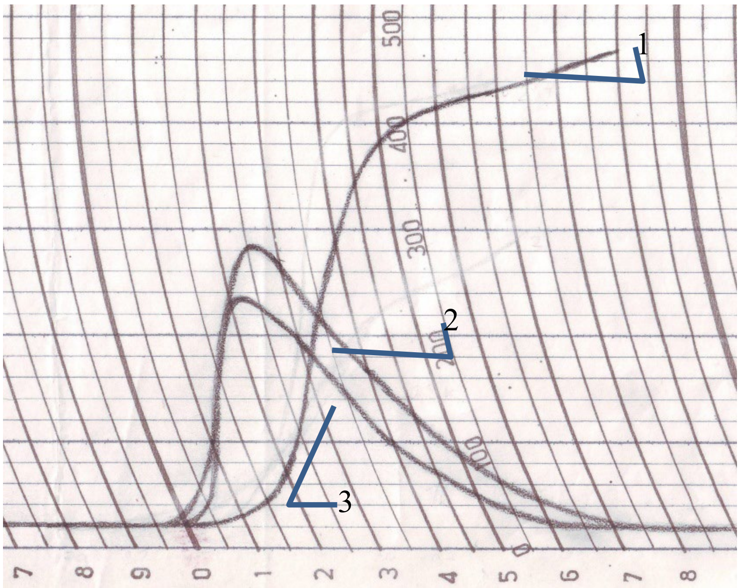

Figure 24 − Amylograms of viscosity changes in the "wheat starch - Tween 20" model systems at citric acid concentrations, %: 1 - 0; 2 - 0.5; 3 - 1.0.

Thus, for the "wheat starch-Tween 20-citric acid" systems, such a temperature is 92-93°C. An increase in acid concentration contributes to a decrease in the onset gelatinization temperature and the value of the maximum viscosity. This behavior can be explained by the hydrolytic action of the acid, which destroys the structure of the starch granule, promoting the free penetration of water molecules into the granule and, accordingly, its faster swelling – the higher the acid concentration, the more intense the swelling.

To substantiate the recipe composition of the mousses, the combined effect of

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the recipe components on the behavior of the effective viscosity of the "wheat starch - Tween 20" model system was studied with a sugar content of 10.0% and a citric acid content in the range of 0-1.0% (Figure 25) [60].

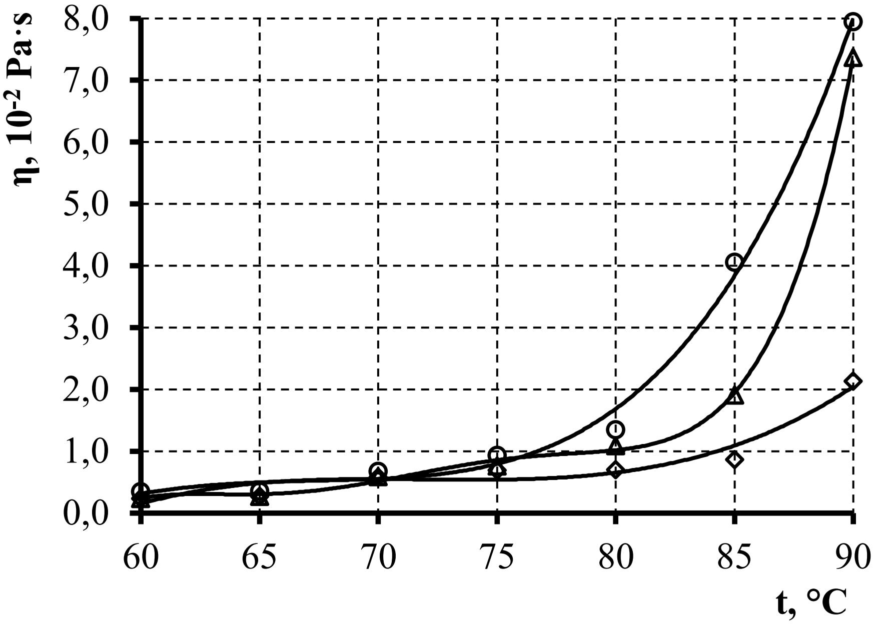

Figure 25 − Changes in the effective viscosity of the "wheat starch - Tween 20 - sugar" model systems with processing temperature at citric acid concentrations, %: ◊ – 0; Δ – 0.5; ○ – 1.0.

Studies of the viscosity behavior of the "wheat starch - Tween 20 - sugar" model systems in the presence of citric acid on a Brabender amylograph revealed that the nature of the curves is most influenced by the change in pH (Figure 26). It was found that the presence of sugar in the "wheat starch - Tween 20 - citric acid" systems contributes to an increase in the maximum viscosity indicators compared to systems without sugar by approximately 100 Brab. units, and is 320-380 Brab. units, while the maximum viscosity of the "wheat starch - Tween 20 - sugar" system at a sugar concentration of 10.0% is approximately 660±33 Brab. units.

It was noted that the decrease in viscosity indicators under the influence of acid is greatest at a temperature of 92-93°C. Thus, it can be assumed that under the destructive action of citric acid, starch granules begin to interact with water and sugar molecules earlier and more intensively, thereby increasing in size more quickly, which, in turn,

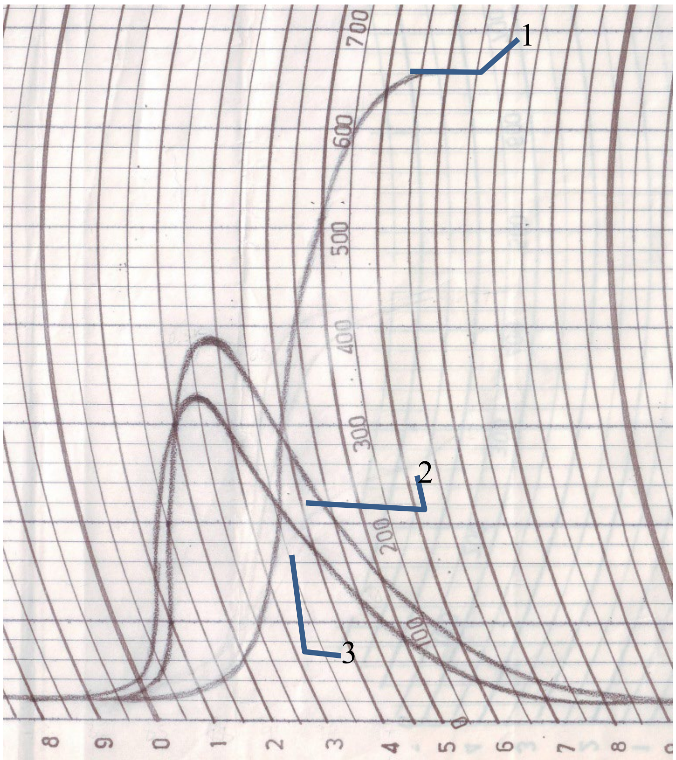

Figure 26 − Amylograms of viscosity changes in the "wheat starch–Tween 20–sugar" model systems at citric acid concentrations, %: 1 – 0; 2– 0.5; 3– 1.0.

leads to an increase in viscosity values. It should be noted that the presence of sugar and citric acid in the model system contributes to an increase in viscosity indicators, which does not contradict the data in the scientific literature. An important point is the practically constant viscosity indicators in the temperature range of 60-70°C, which allows the innovative concept to be implemented. To determine the conditions for the formation of foam-like systems that are stable over time, it is necessary to study the behavior of the recipe components. It is known that a change in the viscosity of foam-like masses contributes to changes in the structural indicators and thereby affects their quality. It should also be noted that the viscosity of the dispersion medium is quite closely related to the temperature factor. Since the recipes for whipped desserts, as a rule, include sugar, with an increase in the concentration of which the viscosity of the liquid in the foam films increases, their destruction slows down and stability increases. However, the ability of sugar to increase the surface tension of solutions significantly complicates the foaming process. Therefore, the influence of sugar on the foaming capacity of solutions depends precisely on the temperature. The effect of sugar is manifested in binding moisture and, accordingly, increasing the viscosity of the system, which contributes to an increase in foam stability, due to the dehydrating effect of sucrose. It was found that the foaming capacity at different sugar contents as a function of temperature has an extreme character, at which the FC values fluctuate in the range of 320-145%, and only for the system with a sugar content of 10.0% (Fig. 27, curve - ▲) is a more linear relationship characteristic, at which the FC values are 280-330%. In contrast, the dependence of foam stability on temperature is characterized by an almost linear relationship: FS increases with an increase in temperature and sugar concentration in the system (Figure 27). It is known that the pH of the medium plays a certain role in the formation and stabilization of foam, which is ensured by the presence of recipe components in food systems that are characterized by a significant acid content. According to the literature, the FC of non-ionic surfactants, which include Tween 20, does not depend on the pH in the range from 3 to 9; however, studies of the viscosity of model systems with citric acid established an increase in viscosity, which can affect the FC and FS indicators.

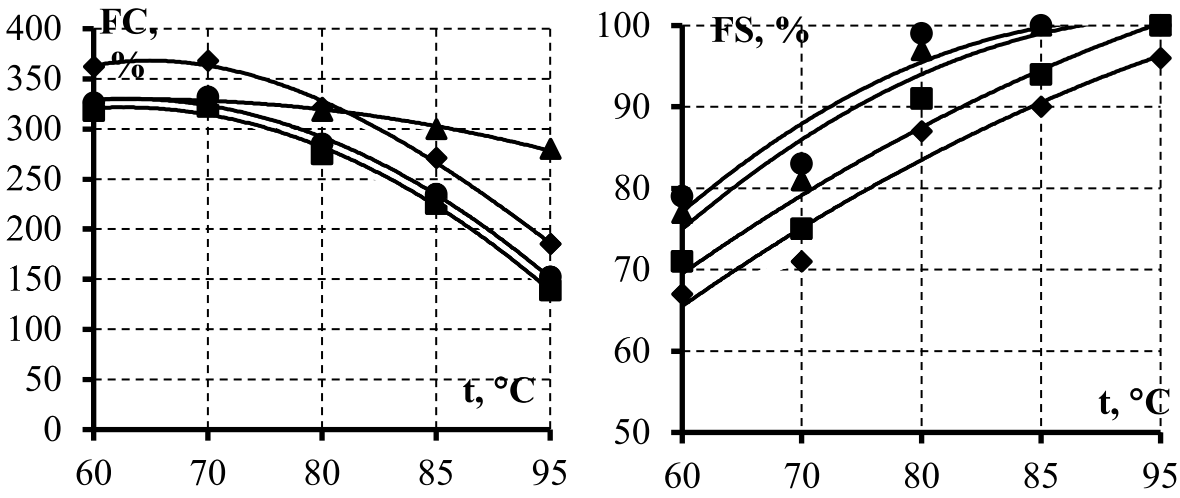

Figure 27 − Foaming capacity and foam stability of the "wheat starch - Tween 20" model systems at processing temperature as a function of sugar concentration, %: ♦ – 0; ■ – 5.0; ▲ – 10.0; ● – 20.0.

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It was established that the foaming capacity (FC) of the model systems with different contents of citric acid (Fig. 28) differs slightly, being at the level of 310-335% at a temperature of 60-70°C and 135-180% at a temperature of 95°C. Similar dependencies are characteristic of the foam stability indicators.

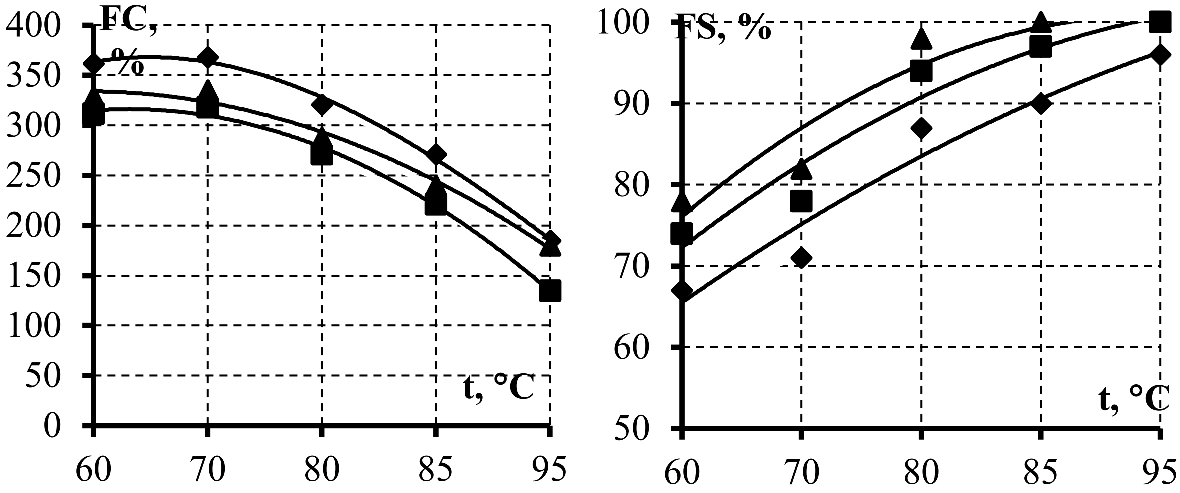

Figure 28 − Foaming capacity and foam stability of the "wheat starch - Tween 20" model systems at processing temperature as a function of citric acid concentration, %: ♦ – 0; ■ – 0.5; ▲ – 1.0.

Based on the obtained data, it can be stated that the components of the model systems and their interaction with each other have a significant effect on viscosity, which, in turn, affects the indicators of foaming capacity and foam stability.

The behavior of a multicomponent system (Figure 29) was studied in terms of foaming capacity and foam stability in order to be able to regulate it.

It was established that the presence of sugar in the model system contributes to a decrease in the foaming capacity (FC) indicator to 330-320% in the temperature range of 60-80°C compared to the analog (without sugar), the value of which is at the level of 360-330%. Citric acid also has a negative effect on the FC of the model system, the combined action of which with sugar leads to FC indicators at the level of 276-250%.

The study of the foam stability (FS) of the aforementioned model system indicates a positive effect of sugar and citric acid on the FS indicators, which reach 100% already at a processing temperature of 85°C.

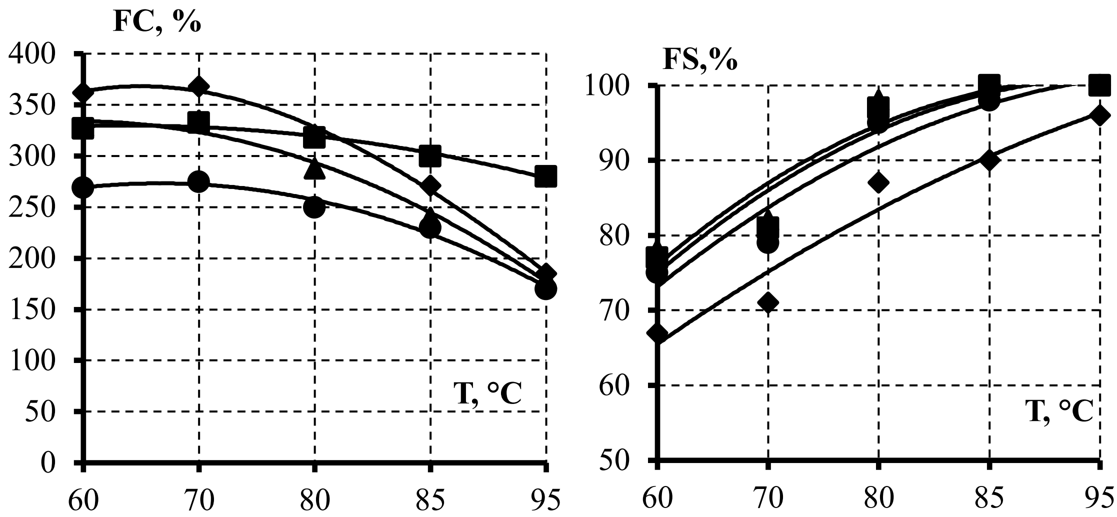

Figure 29 − Foaming capacity and foam stability of the "wheat starch - Tween 20" model systems as a function of processing temperature and concentration, %: sugar ♦ – 0, ■ – 10.0; citric acid ▲ – 1.0; ● – sugar and citric acid.

The conducted experimental studies have proven the possibility of co-using Tween 20 together with wheat starch, which act as a foaming agent and a stabilizer of the system. This became possible due to the unique property of starch to form colloidal dispersions (paste) under hydrothermal treatment under the influence of certain temperatures.

Under these conditions, the degree of hydration of starch dispersions is different, that is, at low temperatures (60-65°C), a 14.0% starch dispersion is characterized by FC indicators at the level of 6.0%, which allows the implementation of mousse technology using wheat starch.

In order to stabilize the foam system, it is necessary to carry out additional heating to a temperature of 85±2°C, which will lead to the gelatinization of the remaining starch, achieving the effect of concentration stabilization of the foam. Under these conditions, the technological process is continuous, allows it to be implemented in industrial production, and to obtain products of stable quality with a prolonged shelf life.

The development of food products (Product Development – PD, Food Research and Development – R&D) is a concept that involves bringing a new product to the market using basic market principles. In other words, it is the process of transforming market needs into ideas that are implemented through a finished product. The development of a new product is a process from the idea stage to the implementation and launch stage [2].

The conducted experimental studies allowed us to substantiate and determine the rational concentrations of ingredients, which were used as the basis for developing the recipe composition and technological process for the production of mousses using wheat starch.

The developed mousses are long-shelf-life products that can be implemented both in food service establishments and at food industry enterprises. The assortment of mousses, which includes 9 items, is normatively fixed in the technical specifications TU U 10.8-01566330-313:2015 "Fruit and vegetable mousses" and in the technological instruction.

The technology for obtaining mousses using wheat starch is an integrated system, within which subsystems D, C, B, A are distinguished, the functioning of which is aimed at obtaining a finished product of appropriate quality.

The technology for obtaining mousses using wheat starch is an integrated system, within which subsystems D, C, B, A are distinguished, the functioning of which is aimed at obtaining a finished product of appropriate quality. The purpose of the functioning of individual subsystems is shown in Table 9.

The functioning of the system is ensured by the functioning of individual components in accordance with the set tasks. It should be noted that the sequential transition from one subsystem to another ensures the obtaining of the final product with the specified properties.

Subsystem D "Receiving raw materials and preparing recipe components" involves receiving raw materials by weight and their incoming inspection in accordance with the requirements of current normative documents, sifting dry ingredients, and freeing fruit or vegetable puree from packaging and dosing it

Table 9 − Structure of the technological system and the purpose of the functioning of subsystems within the new technology

Subsystem	Subsystem Name	Purpose of Subsystem Functioning
A	Mousse production	Obtaining mousse with given properties by implementing the functional properties of its components
B	Formation of mousse consumer characteristics	Sequential execution of operations for mechanical and thermal processing of raw materials
C	Obtaining the recipe mixture	Obtaining a recipe mixture with certain characteristics
D	Receiving raw materials and preparing recipe components	Sequential execution of operations for mechanical processing of raw materials

according to the recipe.

Subsystem C "Obtaining the recipe mixture" involves combining and mixing the pre-prepared ingredients to obtain the recipe mixture.

Subsystem B "Formation of mousse consumer characteristics" involves the sequential execution of raw material processing operations. At the first stage, the recipe mixture is heated to a temperature of 60±2°C with constant stirring and whipping at this temperature, which ensures high foaming capacity indicators. At the second stage, the recipe mixture is further heated to a temperature of 85±2°C (with stirring), which contributes to its stabilization due to the process of wheat starch gelatinization. To ensure microbiological stability and long-term stability, the recipe mixture is subjected to pasteurization at a temperature of 95±2°C for 10 minutes.

Subsystem A "Mousse production" involves obtaining the final product – mousse using wheat starch with determined organoleptic and physicochemical characteristics that are stable over a specified storage period.

The conducted studies allowed for the development of the recipe composition (Table 10) and the technological process for the production of long-shelf-life mousses (Figure 30) [7].

Table 10 − Recipe composition of mousses using wheat starch

Name of raw material	Raw material consumption per 1000g of finished product, g			
	Orange Mousse		Carrot Mousse	
	Gross weight	Net weight	Gross weight	Net weight
Fruit / vegetable juice or puree	797,86*[1]	795,38	267,68*[2]	262,5
Drinking Water	-	-	574,71	574,88
Wheat Starch	147,71	147	105,5	105
White Sugar	105,51	105	105,5	105
Polyoxyethylene Sorbitan Monolaurate (E432, Tween 20)	2,62	2,63	2,62	2,63
Potassium Sorbate (E202)	0,5	0,5	0,5	0,5
Total	1053,7	1050	1056	1050
Yield	-	1000	-	1000

*[1] – mass of juice, *[2] – mass of puree

Fruit and vegetable mousses made with wheat starch are a new type of food product with a foamed structure that is characterized by a long shelf life. To confirm this, the organoleptic, physicochemical, microbiological, and safety indicators of the finished product were defined.

The study of the quality and safety indicators of the new products was conducted on a sample of "Orange" Mousse (made from juice) and "Carrot" Mousse (made from puree). The data is presented in Table 11 [7].

To define the organoleptic indicators, a scoring scale was developed (Table 12).

A sequential transition from one subsystem to another can result in a finished product with different quality levels, so it is necessary to determine the quality indicators of the mousses by their physicochemical and safety parameters.

The chemical composition of mousses using wheat starch was determined (Table 4.5) [7]. It was found that the product is characterized by a moisture content of 65.84...78.46%, contains an insignificant amount of fat (up to 0.05±0.003). The protein and carbohydrate content varies within the range of 0.42...0.59% and 20.08...32.16% respectively.

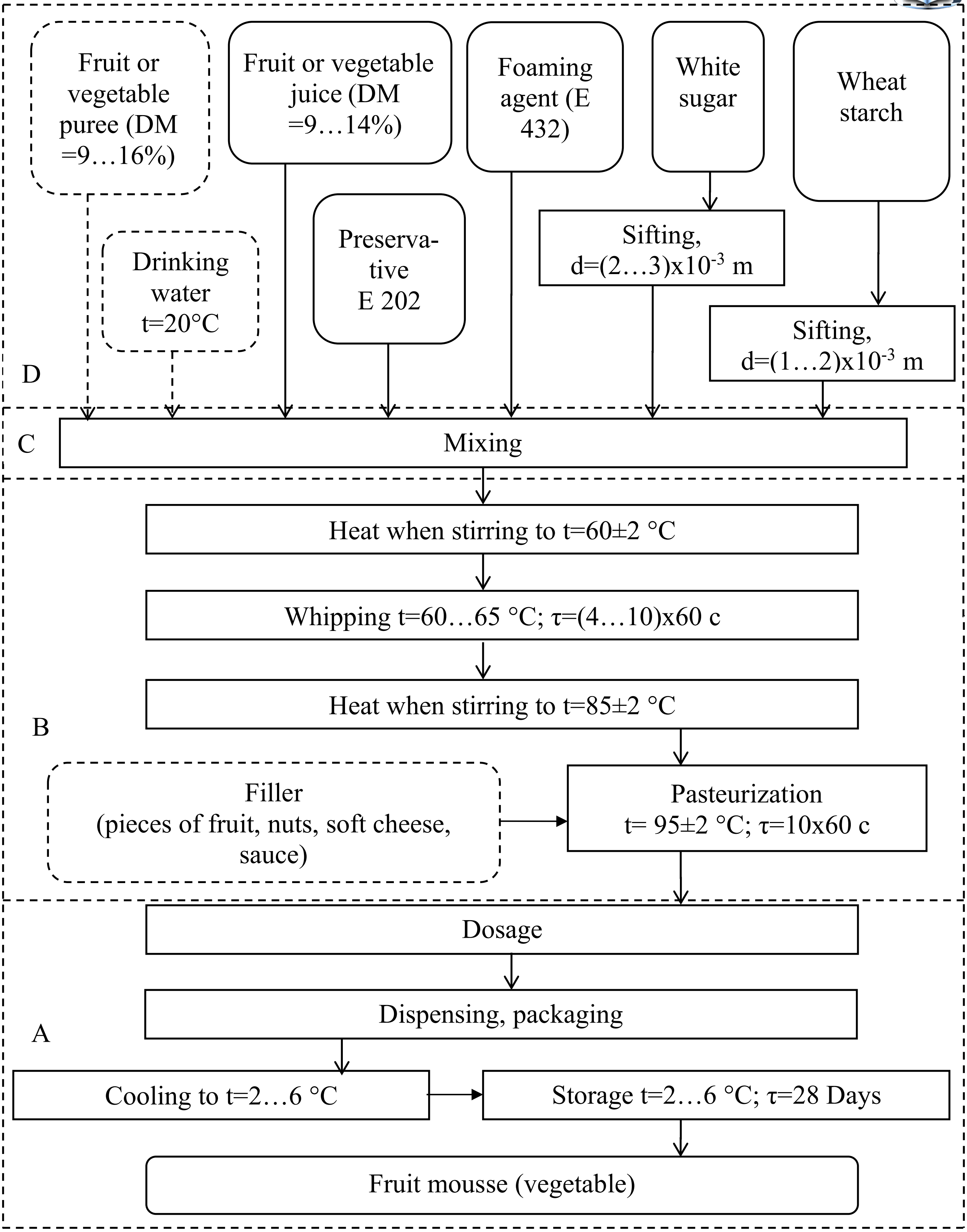

Figure 30 − Technological scheme of mousses production using wheat starch.

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Table 11 − Organoleptic indicators of mousses using wheat starch

Indicator	Mousse name	
	Orange	Carrot
Appearance	a delicate, fine-pored, fluffy, and slightly springy mass	a delicate, fine-pored, fluffy, and slightly springy mass
Consistency	foamy, fine-pored, homogeneous throughout the mass, non-flowing, stable	foamy, fine-pored, homogeneous throughout the mass, non-flowing, stable
Color	homogeneous, corresponding to the color of an orange. Uniform throughout the volume.	homogeneous, corresponding to the color of a carrot. Uniform throughout the volume.
Smell, Taste	characteristic of orange. Pleasant taste from sweet to sweet-sour. No off-flavors or off-smells are allowed.	characteristic of carrot. Pleasant taste from sweet to sweet-sour. No off-flavors or off-smells are allowed.

Table 12 − Scale for general organoleptic evaluation of mousses using wheat starch

Quality indicator	Quality level, points				
	5	*4*	*3*	*2*	*1*
Appearance	Delicate, fine-pored, fluffy, and slightly springy mass	Delicate, fine-pored, fluffy	Mass with non-uniform porosity	Mass showing signs of moisture separation	on-uniform mass with moisture separation
Consistency	Foamy, fine-pored, homogeneous throughout the mass, non-flowing, and stable	Foamy, fine-pored mass with isolated large pores, non-flowing, and stable	Porous mass with a large number of non-uniform pores, non-flowing, and stable	Foamy, non-uniform, and pasty mass	Non-uniform, flowing, and unstable mass
Color	Homogeneous, corresponding to the color of the raw material. Uniform	Homogeneous, corresponds to the color of the raw material	Non-uniform throughout the volume, corresponds to the color of the raw material	Non-uniform throughout the volume	Does not correspond to the color of the raw material

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Quality indicator	Quality level, points				
	5	4	3	2	1
	throughout the volume				
Smell	Characteristic of the raw material. No off-smells are allowed	Characteristic of the raw material	Characteristic of the raw material, poorly expressed	Characteristic of the raw material, poorly expressed	With an off-smell
Taste	Pleasant taste from sweet to sweet-sour. No off-flavors are allowed	Pleasant taste from sweet to sweet-sour	Neutral or unbalanced taste	Unpleasant, sour taste	With an off-flavor

Table 13 − The chemical composition of mousses using wheat starch

Indicator name	Content, %	
	mousse "Orange"	mousse "Carrot"
Mass fraction of moisture, %	66,34±3,29	78,46±3,92
Mass fraction of fat, %	-	0,05±0,003
Mass fraction of proteins, %	0,59±0,03	0,42±0,02
Mass fraction of carbohydrates, %	32,16±1,61	20,08±1,00
Mass fraction of ash, %	0,25±0,01	0,44±0,02

The microbiological indicators of the mousses were investigated (Table 14) [7]. It was determined that their values comply with the requirements of regulatory documents: throughout the specified shelf life (28 days), pathogenic microorganisms, including *Salmonella*, coliforms (BGKP), *Staph. aureus*, *Proteus*, molds, and yeasts, were not identified. The total plate count (TAPC) was 1×101 per gram, which does not exceed the established norms.

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Table 14 − Microbiological indicators of mousses using wheat starch

Indicator name	Indicator value	
	according to regulatory documentation	Actual Content
Pathogenic microorganisms, in particular the genus *Salmonella* in 25 g of product	Not allowed	Not found
Mesophilic aerobic and facultative-anaerobic microorganisms CFU in 1 g of product, no more than	1×103	1×101
Bacteria of the Escherichia coli group (coliforms) in 1 g of product (cm^3)	Not allowed	Not found
Staph.aureus, per 1 g product **(**cm^3**)**	Not allowed	Not found
Proteus, in 0.1 g product (cm^3)	Not allowed	Not found
Number of molds, CFU in 1 g, not more than	50	Not found
Amount of yeast, CFU in 1 g, not more than	50	Not found

The results of the toxicological studies (Table 15) indicate that the developed products meet the safety requirements of the regulatory documentation [7].

Table 15 − Toxic indicators of mousses

Indicator name	Permissible levels according to regulatory documentation, mg/kg, no more than	Actual content, mg/kg
Lead	0,4	0,05±0,01
Arsenic	0,2	0,04±0,001
Cadmium	0,03	0,02±0,001
Mercury	0,02	0,005±0,0001
Aflatoxin B_1	0,005	0,002±0,0001

Changes in the organoleptic and microbiological indicators of the mousses made with wheat starch were studied over a 28-day storage period (Table 16) [7].

Mousses were stored in airtight polyethylene packaging at a temperature of 4±2°C and relative humidity not exceeding 75%. The organoleptic evaluation and microbiological analysis were conducted on the first and twenty-eighth days of storage.

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Table 16 − Microbiological indicators of mousses during storage

Showman	The value of the indicator according to regulatory documentation	Actual content for storage, days			
		0	7	14	28
Pathogenic microorganisms, in particular the genus *Salmonella* in 25 g of product	Not allowed	Not found	Not found	Not found	Not found
Mesophilic aerobic and facultative-anaerobic microorganisms CFU in 1 g of product, no more than	$1 \cdot 10^3$	$1 \cdot 10^1$	$2 \cdot 10^1$	$7 \cdot 10^1$	$1 \cdot 10^2$
Bacteria of the Escherichia coli group (coliforms) in 1 g of product (cm^3)	Not allowed	Not found	Not found	Not found	Not found
Staph.aureus, per 1 g product **(**cm^3**)**	Not allowed	Not found	Not found	Not found	Not found
Proteus, in 0.1 g product (cm^3)	Not allowed	Not found	Not found	Not found	Not found
Number of molds, CFU in 1 g, not more than	50	Not found	Not found	4	10
Amount of yeast, CFU in 1 g, not more than	50	Not found	Not found	5	10

It was found that the organoleptic characteristics such as color, taste, and smell remained stable throughout the storage period. The consistency was described as delicate, foamy, and fine-pored, with the appearance of some isolated large pores (Table 17). The average diameter of the air bubbles increased slightly from 118.6×10^{-6} m to 130.67×10^{-6} m.

Table 17 − Characteristics of air bubbles of ready-made mousses

Bubble diameter, $\times10^6$ m	Bubble content, %	
	freshly prepared	28 days of storage
80,0… 90,0	15,66	10,81
90,0… 100,0	14,46	9,46
100,0… 110,0	10,84	8,11
110,0… 120,0	12,05	9,46
120,0… 130,0	10,84	12,16
130,0… 140,0	9,64	6,76
140,0… 150,0	10,84	12,16
150,0… 160,0	8,43	4,05
160,0… 170,0	6,02	12,16
170,0… 180,0	-	5,41
180,0… 190,0	-	5,41
Average diameter of bubbles, $\times10^6$ g.	118,60	130,67

The microbiological analysis during storage showed a slight increase in the total plate count (TAPC) from 1×10^1 to 1×10^2 per gram. Molds and yeasts appeared on day 14, but their count did not exceed 10 per gram by day 28. Therefore, it can be concluded that the microbiological indicators remained within the permissible limits specified by regulatory documents throughout the entire shelf life.

Thus, these microbiological studies confirm that storing mousses with wheat starch at a temperature of 4±2∘C and relative humidity not exceeding 75% ensures stable consumer characteristics for 28 days.

One of the most important goals of the state's social policy is to improve the structure of nutrition and provide the population with high-quality food products. The understanding of the importance of food safety and quality is becoming increasingly significant worldwide, and particularly in Ukraine.

Public catering establishments (PCEs) are a crucial link in the chain that delivers products from processing and food industries directly to consumers. Therefore, a key issue for Ukrainian PCEs is the production of high-quality and safe culinary products, which will allow them to be more competitive in the restaurant market. The challenge of ensuring the production of quality and safe products in PCEs, compared to industrial food enterprises, is caused by the following factors: a wide assortment of raw materials, semi-finished products, and finished products sold in PCEs; the presence of both heat-treated and non-heat-treated dishes; the simultaneous preparation of a large number of dishes from raw materials of plant and animal origin; limited space for storage, preparation, and sale, usually within one shared area; the limited shelf life of both raw materials and finished products before sale. These factors create many risks in the production of culinary products in PCEs that must be identified and eliminated [2].

A very important aspect of the technology's viability is ensuring its food safety. From the perspective of a Hazard Analysis and Critical Control Point (HACCP) system, the following hazards and preventive actions for mousse technology have been identified (Table 18).

Table 18 − Hazard analysis and critical control points for mousse

Stage/Operation	Regimes, Parameters	Preventive Actions	Hazard Control
Sieving	d=1…6 mm	Reducing the impact of biological (microbial contamination), physical (preventing foreign impurities), and chemical (reducing contaminant concentration) factors.	Failure to perform this operation increases the likelihood of biological, physical, and chemical hazards.
Component dissolution	t=4…6°C		
Mixture whipping	τ =(4…6)x60 s	Mousse structure formation.	Failure to perform this operation properly promotes mechanical protein denaturation, resulting in a compromised mousse structure
Structure formation	T= +1…+6ºC, τ = (1…2)x3600s	Mousse structure formation	Failure to perform this operation properly increases the likelihood of biological hazards
Sales/Serving	t=70°C		Changing the timing and conditions of sale increases the probability of a decline in organoleptic qualities

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The analysis of the "Mousse base preparation" module and the identification of critical control points allowed for the visualization of the types and stages of control (Fig. 31).

As shown, several control points can be identified at different stages of the mousse production process. Failure to follow the specified regimes and parameters can lead to a decrease in the quality and/or safety of the finished product. The determination of critical control points must be based on a detailed analysis of the technological process and a thorough understanding of the changes that occur in the technological system due to technological impact, temporary storage, and sales stages.

The use of the improved mousse technology with wheat starch significantly increases the consumer value of the new product compared to its analogues. To confirm this, a comparative evaluation of the new product and an analogue was performed based on characteristics such as caloric content, stability of consumer properties over time, and raw material composition.

The evaluation was based on the results of a survey of professionals and specialists in the food production industry. The required number of experts (m) was determined using Formula 14:

$$m = \frac{t_\alpha^2}{\varepsilon^2}, \qquad (14)$$

where α – is the confidence probability (reliability), %;

ε – the maximum permissible error;

t_α – the tabulated value for α.

Assuming that α is 95.0% and Δ is 0.5, the tabulated value of t is 1.96. It was determined that surveying 15 experts is sufficient to evaluate the consumer benefits of the new product, and 17 people were actually surveyed. The ranking of consumer characteristics was conducted based on the criterion "maximum score = most significant characteristic." The survey results are presented in Table 19.

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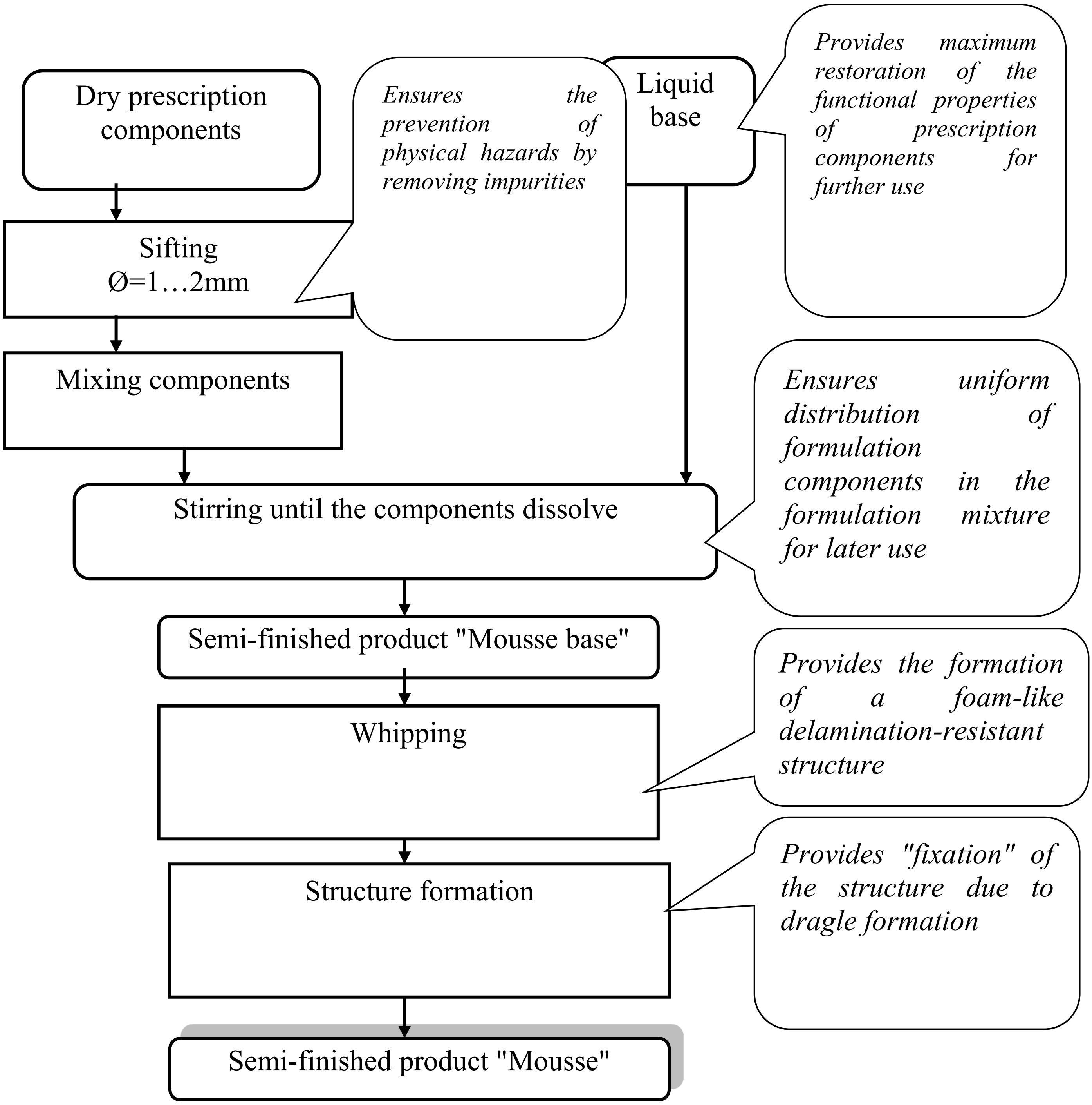

Figure 31 – Analysis of the "Mousse base preparation" module and establishment of critical control points

The quantitative assessment of the significance of individual components of consumer value was performed using the following relationship:

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$$\beta_i = \frac{\sum_{j=1}^{m} x_{ij}}{\sum_{i=1}^{n}\sum_{j=1}^{m} x_{ij}}, \qquad (15)$$

where β_i – is the significance of the i-th characteristic;

x_{ij} - is the number of points assigned by the *j*-th expert to the *i*-th characteristic.

The level of agreement among experts regarding the significance of individual characteristics was confirmed by Kendall's coefficient of concordance (W):

$$W = \frac{12 \times S}{m^2 \times (n^3 - n)} = \frac{12}{m^2 \times (n^3 - n)} \left[\sum_{j=1}^{m} \left[\sum_{i=1}^{n} a_{ij} - \frac{\sum_{j=1}^{m}\sum_{i=1}^{n} a_{ij}}{n} \right]^2 \right], \qquad (16)$$

where W – the coefficient of concordance;

a_{ij} – the rank of the *i*-th characteristic given by the *j*-th expert;

m – the number of experts;

n – the number of characteristics.

The value of the coefficient of concordance (W=0.82) indicates a high degree of agreement among the experts. The significance of the coefficient of concordance itself was verified using the Pearson χ^2 criterion.

A comparison of the actual and critical values of the Pearson χ2 criterion confirmed a high level of expert consensus, which served as the basis for determining the weighting coefficients of the components that form the consumer value indicator of the product developed using the improved technology (Table 20).

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Table 19 − The result of the expert survey and its statistical characteristics

No. s/p	Characteristic	Expert's assessment																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	Stability of consumer properties over time	2	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3
2	Calorie	3	1	2	2	3	1	2	1	2	2	2	2	2	2	2	2	2
3	Raw material composition	1	2	1	1	1	2	1	2	1	1	1	1	1	1	1	1	1
4	Together	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
5	Average	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
6	Estimated value	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
7	Factor	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

Continuation of Table. 19

No. s/p	Sum of ranks	Deviation from the mean	Deviation square	Concordance coefficient	Pearson criterion		Weight factor
					actual	tabular (at a significance level of 0.05)	
1	49	15,0	225,0	–	–	–	0,48
2	33	-1,0	1,0	–	–	–	0,32
3	20	-14,0	196,0	–	–	–	0,20
4	102	–	422,0	–	–	–	1,00
5	34,0	–	–	5064,0	–	–	–
6	–	–	–	6144,0	–	–	–
7	–	–	–	0,82	33,0	5,99	–

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Table 20 − The result of determining the weight coefficients of the consumer value of products components

Characteristic	Rank	Weight factor
Stability of consumer properties over time	49	0,48
Calorie	33	0,32
Raw material composition	20	0,20
Together	102	1,00

To evaluate the consumer value of the new product, expert data were used. The evaluation directions and scale are presented in Table 21, and the results are in Table 22. Considering the significance of individual consumer characteristics and their average values, the integral indicator of consumer value for the new product and the analogue was calculated (Table 23).

Based on the results of the expert evaluation (Table 23), it was concluded that mousses made with wheat starch have a higher level of consumer value compared to mousses produced using traditional technology.

The high consumer characteristics of mousses with wheat starch are a significant driver of consumer demand and a factor in increasing production and sales volumes. It should be noted that the demand for sweet products largely depends on price. The price elasticity of demand is estimated at no less than 1.1. The improvement in the quality characteristics of the new product will be perceived by the consumer as a price reduction of at least 13.0%, which will allow sales volumes to increase by an average of 14.3%.

$$1,1 \times 13,0 = 14,3\%$$

Under these conditions, and considering the share of fixed costs in the product's cost structure, which corresponds to the average for the food industry, a 2.0% increase in product profitability due to improved quality characteristics is expected.

$$16,0 - \frac{16,0}{1,43} = 2,0\%$$

In this case, the additional profit that the manufacturer will receive from introducing the new product into production will be, on average, 1,100...1,600 UAH per 1 ton of the new product (Table 24).

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Table 21 − Directions and scale for assessing the consumer value of products

Characteristic	Score				
	1	2	3	4	5
Stability of consumer properties over time	The stability of consumer properties of a new product over time is much lower than that of an analogue product	The stability of consumer properties of a new product over time is somewhat lower than that of an analogue product	Stability of consumer properties of a new product over time at the level of an analogue product	The stability of consumer properties of a new product over time is slightly higher than that of an analogue product	The stability of consumer properties of a new product over time is much higher than that of an analogue product
Calorie	The calorie content of the new product is much higher than that of the analogue product	The calorie content of the new product is slightly higher than that of the analogue product	The calorie content of the new product corresponds to the analogue product	The calorie content of the new product is slightly less than that of the analogue product	The calorie content of the new product is much less than that of the analogue product
Raw material composition	The raw material composition of the new product is much worse than that of the analogue product	The raw material composition of the new product is somewhat worse than that of the analogue product	The raw material composition of the new product corresponds to the composition of the analogue product	The raw material composition of the new product is somewhat better than that of the analogue product	The raw material composition of the new product is much better than that of the analogue product

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Table 22 − The result of assessing the consumer value of products

Characteristic	Expert score																	Summ, point	Average value, score
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Mousse based on fruit and vegetable juice (control)																			
Stability of consumer properties over time	4	2	3	2	3	4	3	4	3	4	3	4	4	3	4	4	3	57	3,35
Calorie	5	5	3	4	4	4	3	3	3	4	3	4	3	4	4	4	3	63	3,71
Raw material composition	3	4	3	4	4	4	3	3	4	3	3	3	4	3	4	4	4	60	3,53
Together	12	11	9	10	11	12	9	10	10	11	9	11	11	10	12	12	10	180	10,59
Average	4,0	3,7	3,0	3,3	3,7	4,0	3,0	3,3	3,3	3,7	3,0	3,7	3,7	3,3	4,0	4,0	3,3	60,0	3,53
Orange mousse																			
Stability of consumer properties over time	5	5	4	5	4	4	4	5	4	5	4	5	4	4	5	4	5	76	4,47
Calorie	5	5	5	5	5	5	5	4	5	5	5	5	5	4	5	5	5	83	4,88
Raw material composition	4	5	5	4	4	4	4	5	5	5	5	5	5	5	5	4	5	79	4,65
Together	14	15	14	14	13	13	13	14	14	15	14	15	14	13	15	13	15	238	14,00
Average	4,7	5,0	4,7	4,7	4,3	4,3	4,3	4,7	4,7	5,0	4,7	5,0	4,7	4,3	5,0	4,3	5,0	79,3	4,67

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Continuation of Table. 22

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Fruit and berry mousse (control)																			
Stability of consumer properties over time	3	3	4	3	4	4	3	4	4	3	4	3	3	3	4	3	3	58	3,41
Calorie	3	3	3	4	3	4	3	4	3	4	3	4	3	4	3	4	4	59	3,47
Raw material composition	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4	3	4	66	3,88
Together	10	10	11	11	10	12	10	12	11	11	11	11	10	11	11	10	11	183	10,76
Average	3,3	3,3	3,7	3,7	3,3	4,0	3,3	4,0	3,7	3,7	3,7	3,7	3,3	3,7	3,7	3,3	3,7	61,0	3,59
Carrot mousse																			
Stability of consumer properties over time	5	5	5	5	5	4	4	4	4	5	4	4	5	4	4	5	5	77	4,53
Calorie	5	5	5	5	5	5	5	4	5	4	5	4	5	4	5	5	5	81	4,76
Raw material composition	4	4	5	4	4	4	4	4	5	3	4	5	5	5	5	4	5	74	4,35
Together	14	14	15	14	14	13	13	12	14	12	13	13	15	13	14	14	15	232	13,65
Average	4,7	4,7	5,0	4,7	4,7	4,3	4,3	4,0	4,7	4,0	4,3	4,3	5,0	4,3	4,7	4,7	5,0	77,3	4,55

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Table 23 − The result of assessing the consumer value of products

Characteristics	Bridge coefficients	Mousse based on fruit and vegetable juice (control)	Moose apel sino-viy	Fruit and berry mousse (control)	Mus carrot
Sustainability of consumer properties In Time	0,48	3,35	4,47	3,41	4,53
Calorie	0,32	3,71	4,88	3,47	4,76
Raw material composition	0,20	3,53	4,65	3,88	4,35
Factor	–	3,50	4,64	3,52	4,57

$$0,48\times3,35+0,32\times3,71+0,20\times3,53=3,50$$

$$0,48\times4,47+0,32\times4,88+0,20\times4,65=4,64$$

$$0,48\times3,41+0,32\times3,47+0,20\times3,88=3,52$$

$$0,48\times4,53+0,32\times4,76+0,20\times4,35=4,57$$

Table 24 − The result of the calculation of the economic efficiency of the introduction of the developed mousse technology using wheat starch into production

Source of economic effect	Change in profitability of products, %	Additional economic effect, UAH/t
Improvement of product quality characteristics in comparison with an analogue product:		
1. orange mousse	+2,0	+1639,0
2. carrot mousse	+2,0	+1095,5

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CONCLUSIONS

1. An analysis of the current state of production for sweet dishes with a foamed structure and the use of foaming and structuring agents in their composition led to the conclusion that developing a technology for mousses using wheat starch is a promising and relevant endeavor. This is driven by the need to expand the product range within this category and increase production volumes to meet consumer demand.

2. A review of existing theoretical and experimental research revealed a lack of data in scientific literature regarding the use of native starches as a foaming agent and stabilizer for foamed systems. This highlighted the need for research to obtain scientifically grounded mechanisms for producing stable foamed systems using wheat starch.

3. The patterns for obtaining foamed systems using wheat starch and low-molecular-weight surfactants (Tween 20) and their stabilization for the industrial production of mousses have been scientifically substantiated. It was found that based on foam capacity (440%) and foam stability (89%), the optimal use of Tween 20 is within the range of 0.25–0.3%, which enabled the creation of foamed systems with the required technological characteristics.

4. Mathematical modeling was used to determine the optimal content of mousse components: wheat starch at 10.3% and Tween 20 at 0.24%. A heat treatment temperature of 60°C was found to ensure the whipped structure of the mousses and its stability.

5. The characteristics of gelatinized starch dispersions and their changes under the influence of technological factors were studied. It was established that the presence of sugar in the model system in concentrations of 0-20.0% and citric acid in concentrations of 0-1.0% contributes to an increase in viscosity. It was determined that in the temperature range of 60–70°C, viscosity remains stable at $0.3 \pm 0.01 \times 10^{-2}$ Pa·s, which allows for the implementation of the innovative concept. It was found that the presence of 10.0% sugar and 1.0% citric acid in the model system contributes to a decrease in overrun, and their combined effect results in an overrun of 250–276%. A

study of the foam stability of the aforementioned model system indicates the positive effect of sugar and citric acid, as the foam stability reaches 100% at a processing temperature of 85°C.

6. The principles for stabilizing foamed systems using wheat starch have been scientifically justified. It was found that adding sugar to the "wheat starch - Tween 20" model systems at the beginning of the gelatinization process slows down the increase in viscosity. In the final stage, it helps to set the structure by increasing viscosity, preventing the foam from collapsing due to liquid drainage through Plateau channels. It was proven that at lower temperatures (60-65°C), the 14.0% starch dispersion has an overrun of 6.0%, which makes the technology for mousses with wheat starch feasible.

7. The formulation and technological scheme for the production of fruit and vegetable mousses were scientifically justified and developed. The functioning of this process as a technological system was also studied. The key quality and safety indicators of the new products, their nutritional value, and their changes during storage were determined.

8. The regulatory and technological documentation (technological instructions for the production of fruit and vegetable mousses) that governs the technological process for producing mousses with wheat starch was developed and approved. The key quality and safety indicators were studied, and the storage conditions and shelf life were justified as 28 days at a temperature of 4±2∘C and relative humidity not exceeding 75%.

9. The social impact of introducing mousses with wheat starch was confirmed. This impact includes the expansion of the product range, improved quality, and the creation of products with a long shelf life. Based on a comparative analysis of the quality characteristics of the mousses, it was concluded that the new product has a higher value for consumers compared to analogue products.

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