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Collective monograph

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CHAPTER 6

Improving the quality of dairy sauces by using condensed low-lactose milk whey

Yuliia Honchar
Victoriya Gnitsevych

Abstract

For optimal functioning of all organs and systems in the human body, nutrition must be complete and balanced. This is achieved by improving recipes and production technologies of existing food products to preserve their nutritional properties or provide them with new properties. In the presence of associated diseases, especially food allergies, malabsorption or even intolerance to certain food substances, the existing range of food products should be expanded by developing technologies for special nutrition. Mayonnaise products, popular among consumers but not highly biologically valuable or balanced, cannot be included in the diet of individuals allergic to egg products. There have been efforts to replace egg ingredients in mayonnaise with plant-based proteins, but whey proteins in mayonnaise products have not received enough attention. Although secondary dairy raw material – milk whey- is a valuable and cost-effective resource that must be processed, searching for its applications is ongoing. Additionally, mayonnaise products based on whey can not only expand the range of sauces for people allergic to eggs but also serve as a source of animal proteins for lactose-intolerant individuals after lactose removal. This new direction of its use is crucial because previous studies have shown that excluding lactose-containing foods from the diet or partially restricting them does not improve human health. This issue can be addressed using low-lactose protein-carbohydrate dairy raw materials – processed milk whey.

This chapter of the monograph presents research results on the possibility of using fermented mashed pumpkin pulp (FMPP) with a high content of pectin and condensed in vacuo low lactose milk whey (CLLW) in emulsion sauces similar to mayonnaise. Rational oil emulsification parameters have been established, and the characteristics of model samples using FMPP and CLLW in different ratios have been studied. The quality of sauces with an emulsified oil volume of 60 % has been evaluated.

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To establish the rational ratio of main components in the semi-finished product, the rheological properties of model systems have been studied, including their influence on the formation of structuring indicators, such as emulsifying properties. The possibility of using a protein-carbohydrate semi-finished product (SFLLW) based on CLLW and FMPP as a base for emulsion-type sauces like mayonnaise has been demonstrated.

Keywords

Sauce, emulsification, mayonnaise, egg-free sauce, milk whey, fermented mashed pumpkin pulp with a high content of pectin, condensed in vacuo low lactose milk whey, model of the system, lactose intolerance, lactose malabsorption.

6.1 Introduction

Nutrition is one of the most important factors in human life, directly influencing health, productivity, and physical and mental development. For optimal functioning of all organs and systems in the body, nutrition must be complete and balanced.

The issue of rational nutrition among the population holds significant social importance. It plays a crucial role in ensuring the quality and longevity of human life and their health. In Ukraine, the most significant disruptions in the food system include excessive consumption of animal fats and carbohydrates, alongside a deficit of complete proteins of animal origin, polyunsaturated fatty acids, micronutrients, vitamins, and dietary fibers. Therefore, scientists are tasked with creating a range of new products with functional purposes that improve the nutritional status of individuals.

Global trends in nutrition are associated with creating an assortment of functional products that contribute to strengthening public health and reducing the risk of nutrition-related diseases. This task is addressed by including functional ingredients in food products, positively affecting one or several physiological functions of the human body. The creation of functional food products is based on modifying traditional (classical) technologies, allowing for incorporating beneficial ingredients into the finished product within the physiological norms of their consumption (10–50 % of the average daily requirement).

At the same time, the body may find it difficult to absorb nutrients in certain diseases. A common barrier to the complete or partial absorption of certain groups of nutrients is food allergy, intolerance, malabsorption or sensitivity to it. A food allergy happens when the immune system overreacts to a specific protein. Unlike food allergies, food intolerances do not involve the immune system but are missing the enzymes that break down nutrients. The lighter form of intolerance is malabsorption, when the concentration of enzymes isn't enough to break the nutrient completely. Non-disease sensitivity is a new syndrome of intolerance. Free from this specific nutrient, the diet leads to a complete regression of symptoms. Symptoms can range from mild (rashes, gasses, hives, swelling, itching, etc.) to severe (trouble breathing, loss of consciousness, etc.). More than 170 foods have been reported to cause allergic reactions. The major food allergens are milk because of the lactose as a carbohydrate and egg because of the complex of proteins. Therefore, there is a demand for traditional products in which ingredients that may cause a negative reaction in the body are replaced. One type of such product is sauces. The main sauces and their derivatives mainly contain products that can cause such reactions: milk, eggs, nuts, etc. Therefore, considering the prospects and directions for improving sauce production for special diets is worth considering.

Overall, the global market for food and beverage products aimed at improving health and overall well-being continues to grow at an average rate of 8 %. The number of people consuming functional food products and dietary supplements is constantly increasing.

The international market for sauce products is diverse. However, all products in this category have the same significance, namely as a flavor enhancement for dishes. In this market, the success of launching new products depends on continuously monitoring consumer preferences and analyzing competitive products.

The global mayonnaise market demonstrates steady growth rates, with a projected production increase of approximately 4 % over the next five years [1].

According to data from the State Statistics Service of Ukraine, the Ukrainian Customs Service, and the company "Pro-Consulting", the competition level in the Ukraine sauce market is high, primarily from domestic manufacturers. Mayonnaise production holds the largest market share, accounting for 57 % of the market structure [2].

Mayonnaise is a popular condiment known for its creamy texture and tangy flavor. It is typically produced from a blend of oil, vinegar or lemon juice, egg yolks, and seasonings. The mixture is emulsified to create a smooth and stable sauce. Emulsified fat-containing products play a significant role in nutrition because when fats are consumed, the human body absorbs them only after they are converted into an emulsified state.

It is widely employed as a spread for sandwiches, burgers, and wraps and serves as a base for various dressings and sauces. Its versatility has made it a staple in culinary applications in home kitchens and the commercial food industry. Additionally, it is known for enhancing the taste and mouthfeel of dishes, contributing a rich and satisfying element. Nowadays, it is incorporated into dips and marinades due to its creamy nature across the globe.

The growing food service industry primarily drives the market. In addition, the increasing number of products for convenient and easy meal alternatives, including wraps, salads, and sandwiches, is influencing the market growth. Also, the growing health awareness among consumers, the rising product demand in global culinary options, and the rising disposable incomes are augmenting the market growth. Moreover, introducing health-conscious product variations, including eggless, gluten-free, lactose-free, low-fat, vegan, and vegetarian mayoresses offerings, represents another major growth-inducing factor. Besides this, the shift in consumer lifestyles and the widespread product integration within the food and beverage sector are propelling the market growth. The convenience of procuring products from various retail outlets contributes to market growth. Furthermore, the growing recognition of mayonnaise's nutritional value and versatility creates a positive market outlook. This chapter explores the problems of improving the quality of sauces.

In Ukraine, the production of mayonnaise and mayonnaise-based sauces is regulated by the State Standard of Ukraine 4487:2015, "Mayonnaises and Mayonnaise Sauces. General Technical Conditions". According to section 3.1 of DSTU 4487:2015, mayonnaise is a finely dispersed homogeneous emulsified product with a fat content of not less than 50 %, made from oil, water, egg products, with or without the addition of processed milk products, food additives, and other food ingredients (according to the recipe). Furthermore, according to section 5.4.4 of DSTU 4487:2015, mayonnaise produced under the traditional name "Provansal" must have a fat content of 67 % and an egg product content, including fermented ones, calculated on dry egg yolk of not less than 1.5 %. However, despite their functionality, eggless recipes in industrial production can only be called "a-la mayonnaise", indicating the imperfection and non-inclusivity of Ukrainian legislation. Nevertheless, the existing demand for such products must be met.

First and foremost, excluding egg raw materials from mayonnaise formulation meets the needs of individuals with egg allergies, which affects approximately 1 in 10 adults [3], as well as vegetarians [4].

In their work, Nopparat Prabsangob and Sunsanee Udomrati used acid-modified pea protein isolate and okara cellulose crystal as a co-emulsifier to improve the physicochemical stability of fat-reduced eggless mayonnaise [5]. However, the resulting product had a drawback of a gelatinous consistency and a specific aroma. Miray Büyük, Ada Ata, and Ahmet Yemenicioğlu proposed using aquafaba as a source of mainly water-soluble proteins and carbohydrates, used in combination with citrus pectin and grape seed extract [6] as a co-emulsifier. The major benefit of this technology is related to the reduction of emulsion droplet size, but it still has short-term storage, high risks of lost emulsion and additionally specific organoleptic characteristics.

Another work of innovative technology for developing egg-free mayonnaise was shown, which uses β-carotene and soy-protein binding but has an inappropriate intensive yellow colour [7]. Another obvious disadvantage of this technology is the use of soy proteins since soy is an allergen. However, there are relatively few studies dedicated to using whey proteins for preparing mayonnaise recipes, and all of them are focused on creating recipes for low-fat sauces. The majority of studies also involve the use of dried demineralized whey. However, no studies have been conducted regarding using an intermediate product of its production – condensed whey – including partial demineralization of about 40 % instead of 90 %. An essential point in this case is the necessity of prior lactose removal to prevent crystallization and make this product accessible to individuals with lactose intolerance and malabsorption. This is particularly important since the percentage of such individuals among the populations of Asian and African countries is 90 %, Southern Europe – 70 %, Australia, Northern Europe, and North America – up to 17 %. In Central Europe, it's 30 %; in Southern Europe – 70 %; and in Ukraine, 16 % of the population has been officially diagnosed and confirmed by laboratory tests with malabsorption, with many undiagnosed cases additionally [8]. Including low-lactose food products based on hydrolyzed protein-carbohydrate milk raw materials (PCM) in production will allow the development of a product suitable for consumption by a wide range of consumers.

Acid whey is cheap and a lot in sizes souse, the potential of which in Ukraine is not fully realized for food purposes. As of the first half of 2020, 735 thousand tons of whey were produced, with only 30.4 thousand tons subject to processing, while the rest was discarded as waste [9]. Therefore, the priority issue becomes the creation of technologies for low-lactose semi-finished products based on them for further use in special food product technologies.

Structuring agents are needed to develop emulsified sauce products based on whey proteins. Excellent structuring properties distinguish plant raw materials with a high content of pectin substances. Pumpkin pulp can be used as such raw material, characterized by potential properties of structuring agents, structure stabilizers, and regulators of sensory indicators of food products. However, in its untreated form, the amount of pectins is insufficient for use as structuring agents.

Based on previous research, a protein-carbohydrate semi-finished product based on low-lactose condensed whey and fermented pumpkin puree (SFLLW) was developed [10]. However, the issue of researching emulsified sauce products based on it was not fully explored.

Therefore, this monograph chapter is dedicated to investigating the quality of emulsified sauces, using mayonnaise as an example, with the utilization of semi-finished based on low lactose whey.

6.2 Organization and research methods

An **innovative strategy** for developing emulsified sauce technology has been proposed to address physiological, raw material, environmental, technological, and economic issues.

In this regard, the main principles of mayonnaise sauce development and requirements for its technological properties were formulated. It should:

1. Meet the needs for essential nutrients of individuals with malabsorption who have restrictions on lactose consumption and egg intolerance.
2. Be aggregate-stable immediately after production and during storage.
3. Be produced from locally available raw materials in Ukraine with the realization of their food and functional-technological properties.
4. Reduce the volumes of secondary raw dairy materials (unused milk whey), which are potential environmental pollutants.
5. Make the technological process of sauce production based on SFLLW accessible to both high-capacity productions, small craft manufactories and restaurant establishments.

Implementing these principles is possible only through reasoned and targeted influence on the selected dairy and plant raw materials to most fully utilize their technological properties.

Based on the provisions of the innovative development strategy, a working hypothesis was formulated, which suggests that the use of plant raw materials as a source of low-esterified pectin substances and fermented milk whey as a source of proteins, calcium, phosphorus, low-lactose, with directed regulation of functional-technological properties during fermentation and thickening, using a low-lactose semi-finished product based on whey, will allow obtaining functional emulsified sauce.

The **aim** of the work is to investigate the rheological properties of model sauce systems, based on SFLLW, condensed fermented whey with reduced lactose content, and fermented pumpkin puree with increased pectin content.

The **object** of the research is the technology of mayonnaise emulsion sauce based on SFLLW and its quality.

The **subject** of the research is SFLLW, functional-technological properties of model systems based on SFLLW, and the quality of the developed culinary products.

The properties of "Provansal with 67 % fat content" mayonnaise of the classic recipe were investigated as a control sample by own production.

The basis for SFLLW used in sauce production owes its excellent emulsifying properties to its composition.

Model compositions of SFLLW with FMPP content exceeding 60 % and CLLW content lower than 40 % exhibited unsatisfactory organoleptic characteristics; therefore, they were not used for further research.

To produce SFLLW, pre-fermented milk whey is condensed under vacuum. The condensing process occurs at a reduced pressure of $P=-0.1$ Pa, at a constant temperature of 50±2 °C, for 6·3600 sec. The concentration factor is 10 [11]. As a result of condensation, the effective viscosity index increases, providing grounds for using condensed in vacuo low-lactose milk whey (CLLW) in viscoelastic systems. Adjusting the acidity of CLLW to neutral pH levels is achieved.

Simultaneously, preliminary hydrothermal treatment of pumpkin pulp was carried out, followed by fermentation with enzyme preparation Vetom 1.1. The optimal parameters for the fermentation process in the production of fermented mashed pumpkin pulp (FMPP), which leads to the maximum accumulation of soluble pectin, are a temperature of 55±3 °C, a duration of 15·3600 sec, and a concentration of enzyme preparation of 1.5 % [12].

A key issue in determining the functional-technological properties of the semi-finished product and its nutritional and biological value is establishing a rational ratio of system components.

One of the main requirements for sauce production based on SFLLW is the presence of the necessary texture and the ability to maintain structural characteristics. During the production of emulsion sauces, viscosity (η, Pa·sec) and stability (V, %) are the most indicative parameters during the emulsification stage. These parameters are directly dependent on the pH values of the emulsion system, emulsification temperature (t, °C), oil dripping speed (ν, ml/sec), and the speed of rotation of the mixer's working element (V, 1/sec).

The SFLLW content in sauce model systems varied within 40…90 % with a step of 10 %. The mixture components were stirred at a temperature of 20±1 °C for duration of 60 sec until homogeneity was achieved using the IKA Ultra-Turrax T18 basic homogenizer at $V=11200$ RPM.

The oil droplet size of the emulsions was observed using a Biological digital microscope MICROmed XS-3330 LED, and the volume-weighted diameter (DS, nm) was recorded, where DSD shows the % number of particles with diameter d_i. The measurement was used to provide distribution patterns of the oil droplet sizes.

The effective viscosity was determined using the rotational viscometer BPN-0.2M. The working temperature in the thermostat was +23.3±1.5 °C. Up to five rotation period values were taken for a fixed voltage value, excluding gross errors, and the average value was calculated. The samples' shear stress limit (SSL) was determined by extrapolating the linear section of the curve $\tau=f(\gamma)$ at a shear rate of 100 1/sec, corresponding to values during sensory evaluation during product consumption.

The fat-binding capacity was determined by the amount of vegetable oil (sunflower) required to reach the inversion point. Determination of the phase inversion point to assess the emulsifying ability of model systems was carried out according to the method of O. M. Gurov [13]. Oil was emulsified using the DLH mechanical top-drive mixer with a dissolving attachment, mixing material from top to bottom and bottom to top under high turbulence and cross-force action for 25–35 min, depending on the component ratio. Emulsion stability (ES) was determined by the amount of unlayered emulsion. The emulsion type was determined by dilution in water. The phase inversion point value corresponded to the mass content of oil used in the process.

6.3 Investigation of the rheological properties of model emulsion sauce systems

Various interactions may occur in systems containing milk whey proteins and esterified pectin derived from fermented pumpkin puree. Depending on the temperature, processing time, pH of the medium, ionic strength of the solution, and the ratio of proteins to pectin, complexes may form (intra-molecular, inter-molecular, electron-neutral, charged coacervates) [9]. Therefore, it is advisable to investigate the nature of the interaction between pectin-containing FMPP and whey proteins in CLLW. To assess the effectiveness of SFLLW application, model compositions were studied at different ratios of FMPP to CLLW and amounts of emulsified oil.

The new mayonnaise composition was prepared using CLLW in combination with FMPP at different ratios as an emulsifier. Sample of mayonnaise by own production stabilized with egg yolk powder, was used as control for comparison. The dispersion characteristics were observed visually using a microscope, and the number of oil droplets of different sizes was counted. The results of the calculated average values of the size of emulsified oil droplets in different samples, taking into account the error, are shown in **Fig. 6.1**.

Lower stability was clearly observed for the control sample and the sample with a 90:10 ratio, as indicated by its higher average droplet size. Compared to these samples, those with ratios of 70:30, 60:40, and 50:50 had smaller average oil droplet sizes. This correlated with optical images of the emulsions. The results demonstrated the feasibility of using SFLLW as an emulsifier for preparing emulsion sauce, as expected from its strong emulsifying ability, as previously demonstrated [14].

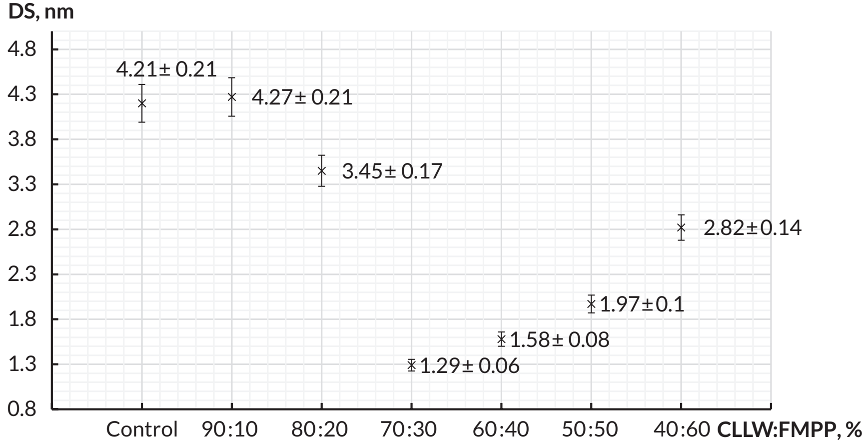

Fig. 6.1 Differences in oil droplet sizes (DS, nm) of emulsion depending on the nature composition of model systems

However, using FMPP in quantities of 30 % and 40 % of the SFLLW mass resulted in smaller droplet sizes. Consequently, this explains the increased physical stability of freshly prepared mayonnaises in these model compositions. The addition of FMPP in quantities of 30 % and 40 % of the SFLLW mass is attributed to improved interfacial activity of whey proteins due to changes in hydrophilicity and hydrophobicity balance, as well as molecular flexibility in the presence of pectins.

For the control sample, a wide range of emulsion droplet sizes was observed (**Fig. 6.2**), with the majority being large in size, indicating lower stability of the control sample.

In comparison to the control, samples with CLLW in the main component ratio of CLLW:FMPP in amounts of 70:30 and 60:40 not only had smaller oil droplets but also showed a denser grouping of sizes. There are sharp peaks in the curves shown in **Fig. 6.2**, indicating high homogeneity of the emulsified droplets in terms of size. However, for the sample with a CLLW:FMPP ratio of 50:50, the droplet size distribution curve was fragmented, indicating the presence of more homogeneous droplets in size and a small but significant number of large droplets. This indicates the reduced stability of such a system, which is consistent with optical images of the investigated emulsion sauces.

The rest of the samples showed significant variations in the ratio of droplet sizes. Although the average sizes of the 40:60 and 80:20 CLLW:FMPP samples were smaller than the control, these systems had significantly lower stability as they tended to separate more rapidly due to uneven droplet distribution. The obtained results demonstrated the effectiveness of using SFLLW as an emulsifier for preparing egg-free mayonnaise, as could be expected from its powerful emulsifying ability, as shown in **Fig. 6.1**, **6.2**. However, using CLLW:FMPP in ratios of 70:30 and 60:40 resulted in smaller droplet sizes with a narrower size distribution structure. This trend corresponded to greater stability in these mayonnaise samples compared to the control sample.

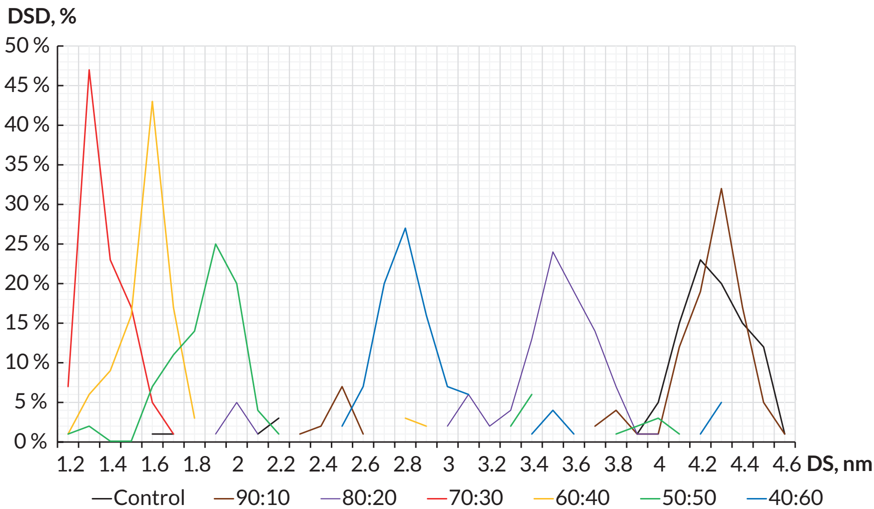

Fig. 6.2 Droplet size distribution patterns of sauce model systems

The interaction between whey proteins and pectin can be evaluated using rheological methods. Rheological methods of investigation can detect abnormal changes in viscosity and shear stress of systems, based on which it can be concluded whether substances interact or not. The results of effective viscosity studies of model systems are presented in **Fig. 6.3**.

As the FMPP content increased from 10 % to 60 %, the effective viscosity increased by 3.1 times. Therefore, it can be concluded that there is no coacervation of protein-pectin complexes and no thermodynamic incompatibility of proteins with pectins at the studied component ratios. In such cases, the viscosity of the system would decrease. The obtained data indicate the interaction of whey proteins and pectins with interpenetrating polymer network structures during micelle formation. This significantly affects the stability of the prepared emulsions. The obtained data were compared with the viscosity of the control sample prepared using a classic recipe.

A shear rate is constant and equal to 100 1/sec.

In a classic mayonnaise, the interaction between egg yolk proteins and oil droplets plays a crucial role in forming a network to stabilize the mayonnaise system. The higher emulsification rate of the control sample could be due to its lower viscosity and larger size of oil droplets in the emulsion (**Fig. 6.1, 6.2**), which reduces the emulsion's dispersing ability.

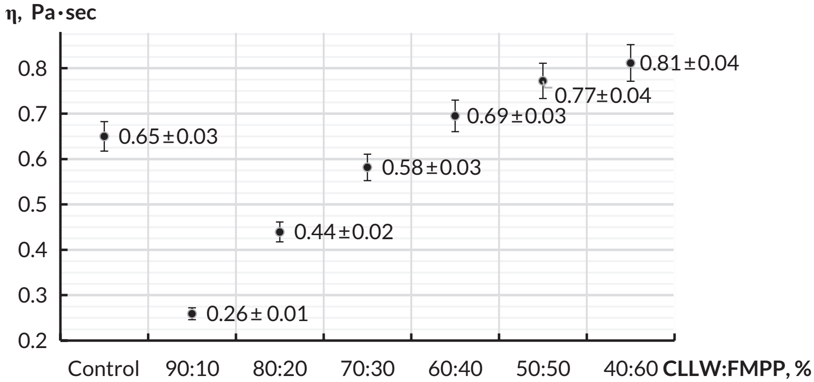

Fig. 6.3 Effective viscosity (η, Pa·sec) of model compositions on the CLLW: FMPP ratio

On the contrary, samples with CLLW:FMPP ratios of 40:60, 50:50, 60:40 exhibited higher viscosity compared to the control. The use of CLLW in combination with FMPP additionally improved the viscosity of mayonnaises, especially at higher FMPP concentrations. These results can be explained by inter- and intramolecular interactions between adsorbed proteins and pectins on the surface of oil droplets, leading to the formation of hydrocolloid networks. Simultaneous or sequential formation of interpenetrating polymeric mesh structures causes microphase separation of proteins and carbohydrates due to incompatibility arising from interchain nodes with subsequent oriented extrusion of pectin molecules onto the protein surface. Increased carbohydrate concentrations in microvolumes lead to enhanced self-association, hydrogen bonding, merging zones of pyranose pectin structures, resulting in faster viscosity growth. This process hampers pectin phase distribution, ensuring the necessary structuring of their structures and stabilizing the system's structure. Furthermore, water-soluble pectins with hydrophilic nature can effectively interact with water, increasing emulsion viscosity. Enhanced viscosity of the water phase can limit oil droplet movement, restricting collision between droplets, leading to improved emulsion stability. Additionally, visible viscosity is closely related to mouthfeel, indicating a velvety texture of food emulsions. Thus, increased mayonnaise viscosity due to SFLLW usage can lead to improved textural characteristics of the product.

Determining the magnitude and dependence of the shear stress limit (SSL) on the component content allows for identifying the possible type of interaction and characterizing the rheological behavior of the systems. It has been established that with an increase in the FMPP content, the shear stress limit also increases. It should be noted that the dependence of SSL on the puree content shows the presence of a breaking point on the curve for the sample with CLLW:FMPP ratios of 70:30 (**Fig. 6.4**).

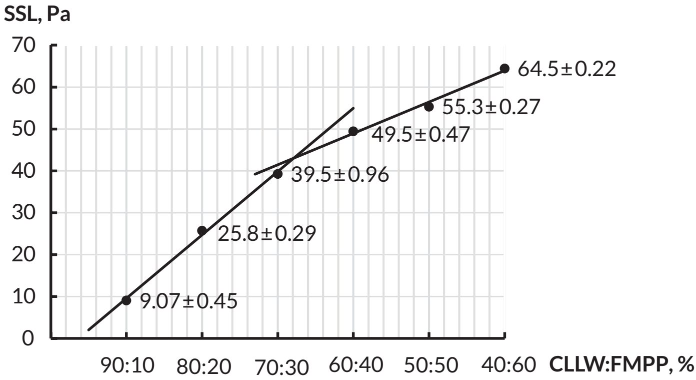

Fig. 6.4 Dependence of SSL (Pa) of systems on the CLLW:FMPP ratio

The break in the curve in **Fig. 6.4** indicates a change in the interaction between proteins and pectins. An increase in the structure-forming ability was observed for the sample with CLLW:FMPP ratios of 70:30. Based on the obtained data, it can be stated that at this ratio of components, SFLLW achieves maximum realization of structure-forming properties during emulsification, and the systems are characterized as visco-plastic. Further, an increase in SSL results from changes in the interaction between whey proteins and pectin. This is evidenced by the SSL rate increase. Presumably, the solubility of complexes, molecular weight, and diffusion coefficient change, which is consistent with studies showing that with an increase in pectin content, the size of protein-pectin particles also increases.

The investigation of shear rate is useful for sensory evaluation of consistency and overall appearance of samples. Since the addition of SFLLW increases the viscosity of mayonnaise due to its high ability to bind free water and oil as stabilizers for the continuous phase. However, samples with CLLW:FMPP at a ratio of 40:60 quickly transitioned from a stage of maximum viscosity to emulsion stratification, indicating insufficient strength of complexes with lower protein content.

It can be concluded that by incorporating SFLLW into the composition of model emulsion sauce systems, it is possible to regulate viscosity over a wide range as a stability factor. Since the effective viscosity opposes the oil emulsification process, leading to significant energy consumption, it is necessary to evaluate the emulsifying capacity of the system. The emulsifying capacity of model systems was assessed by the phase inversion point (**Fig. 6.5**), i.e., conditions under which the system stratifies were determined.

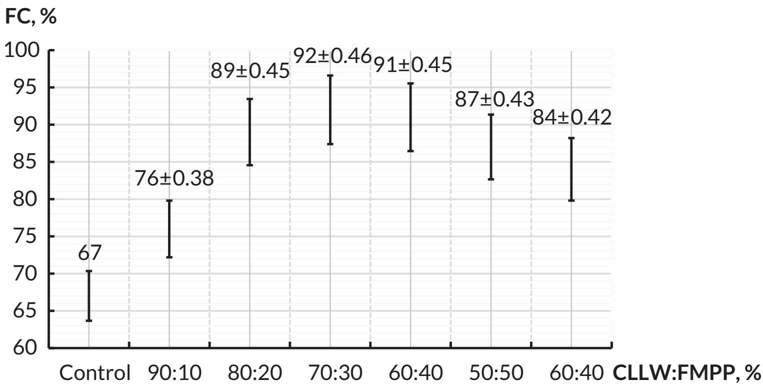

Fig. 6.5 Dependence of the emulsion inversion point (FC, %) of systems on the CLLW:FMPP ratio

To study the behavior of the system and determine the standard inversion point, an analysis of the recipe composition using SFLLW for different ratios of CLLW and FMPP, corresponding to different viscosities, was performed.

To determine the standard inversion point, each pre-balanced sample continued to be emulsified under unchanged system parameters: the stirring speed of the agitator, ambient temperature, and oil dripping rate. The variable was the amount of emulsified oil at which the system stratified.

It has been established that the dependence of the inversion point on the component ratio has an extreme character. In the interval of FMPP content of 0…30 % in SFLLW, the emulsifying capacity increases. A further increase to 40…60 % leads, on the contrary, to a decrease in the emulsifying capacity of the systems by 1.3 times. In systems using CLLW:FMPP at a ratio of 70:30, the phase inversion point of the emulsion corresponds to a fat content of 91…92 %. This is probably due to the formation of complex protein-carbohydrate complexes, the maximum hydrophobicity of which is formed in systems with an FMPP content of 30 %.

With an FMPP content of more than 40 %, the hydrophilic-lipophilic balance may change, dimensional characteristics increase, and as a result, the diffusion coefficient decreases. This negatively affects the emulsifying capacity.

The conducted studies of emulsion stability during emulsification indicate that with an increase in oil content, the stability of the emulsion increases. However, an important factor is the influence of the oil dripping rate, which directly affects the stability of emulsions and the amount of emulsified oil. The optimal emulsification rate of the oil was determined under conditions of constant stirring speeds of the agitator and ambient temperature. The range of analyzed oil dripping rates was 0.09…0.11 ml/s.

As can be seen from **Fig. 6.6**, the effective viscosity index is directly proportional to the oil dripping intensity during its emulsification process. The rational viscosity zone corresponds to effective viscosity indices in the range from 0.586 Pa·sec to 0.640 Pa·sec. These viscosity values corresponded to an oil dripping rate of 0.05 and 0.1 ml/sec. Increasing the oil flow intensity to 0.2…0.4 ml/sec resulted in incomplete emulsification and accelerated the time to emulsion inversion. At the same time, reducing the flow intensity to 0.01 ml/sec led to stratification of the system already at 70 % of the added oil, which is explained by the non-uniform distribution of the oil phase under the established stirring regimes.

Therefore, a model system with CLLW:FMPP in a ratio of 70:30 and oil content of 60 %, with emulsion stability of 98±2 %, is achieved, which meets the requirements of mayonnaise products according to regulatory documentation.

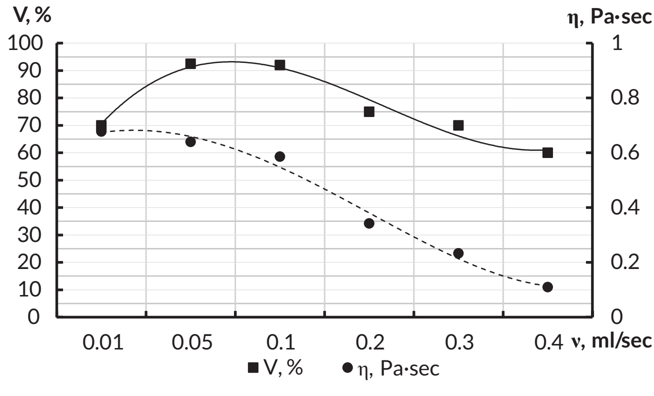

Fig. 6.6 Dependence of the emulsion inversion point (FC, %) and effective viscosity (η, Pa·sec) depends on the oil dripping rate (ν, ml/sec)

It is worth noting that in systems with an oil content of up to 60 % and FMPP content of 40…60 % in SFLLW, emulsion stability remains practically unchanged. However, the system's viscosity based on SFLLW increases in this range. Therefore, it can be assumed that different complexes are formed based on their surface activity and hydrodynamic properties (size, charge, molecular weight) at FMPP contents up to 30 % and at FMPP contents of 40…60 %.

Based on the analysis of the absolute values of emulsifying capacity and emulsion stability, it is possible to recommend a rational ratio of components in model systems based on SFLLW for obtaining emulsion-type sauces, like mayonnaise without egg-products.

Thus, the provided data indicate that using SFLLW to acquire certain functional-technological properties has several advantages. Firstly, this includes increasing the nutritional and biological value and providing products with therapeutic and prophylactic characteristics. Secondly, FMPP is capable of retaining moisture in the product structure, increasing stability, and enhancing the viscosity of emulsion-type sauces with high oil content. Thirdly, in this case, FMPP acts as a colorant and CLLW as a flavor enhancer.

Conclusions

The proposed innovative model for producing emulsion sauces similar to mayonnaise of the new generation involves the use of SFLLW as the main component, which acts as an emulsifier due to the presence of whey proteins and as a structure former due to its high content of soluble pectin.

As a result of the conducted research, the range of values of rational parameters for individual indicators of the technological process of preparing such emulsion sauces has been determined. Therefore, it is objectively justified to establish optimal values.

Studies of rheological and functional-technological properties have allowed to establish that with an increase in the FMPP content, the shear stress of model systems increases. Based on the obtained data, it is stated that with an FMPP content of 30 %, the maximum realization of structure-forming properties is achieved, and the systems are characterized as visco-plastic.

Based on the results of the research on rheological and functional-technological properties, a rational ratio of CLLW:FMPP as 70:30 and 60:40 is substantiated. Such a ratio exhibits high emulsifying and stabilizing properties, allowing to obtain emulsion systems with maximum stability at an oil content of 60 %.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship or otherwise, that could affect the research and its results presented in this paper.

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