Теоретично обґрунтовано та експериментально визначено технологічні параметри обробки пектинвмісної сировини у технології молочно-рослинних фаршів. Досліджено вплив рН середовища, температури та тривалості теплової обробки моркви, гарбуза, кабачків на процес накопичення в них розчинного пектину. Розроблено технологічну схему одержання пюре з овочів, що має підвищену в'язкість і не розшаровується при зберіганні. Це обумовлює доцільність його використання у технології молочно-рослинних фаршів

Ключові слова: пектинові речовини, розчинний пектин, структуроутворювач, молочно-білковий концентрат, молочно-рослинні фарші

Теоретически обоснованы и экспериментально определены технологические параметры обработки пектинсодержащего сырья в технологии молочно-растительных фаршей. Исследовано влияние рН среды, температуры и продолжительности тепловой обработки моркови, тыквы, кабачков на процесс накопления в них растворимого пектина. Разработана технологическая схема получения пюре из овощей, которые имеют повышенную вязкость и не расслаиваются при хранении. Это обуславливает целесообразность его использования в технологии молочно-растительных фаршей

Ключевые слова: пектиновые вещества, растворимый пектин, структурообразователь, молочно-белковый концентрат, молочно-растительные фарши

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DETERMINING TECHNOLOGICAL PARAMETERS FOR TREATING PECTIN-CONTAINING RAW MATERIALS IN THE TECHNOLOGY OF MILK-VEGETABLE MINCES

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1. Introduction

Health of a modern human is largely determined by the character and structure of nutrition. According to statistical data for 2013–2015, consumption by Ukrainian population of such biologically valuable products as milk and milk products decreased by 10.5 %, meat and meat products by 14.6 %, eggs by 14.6 %, fish by 44.5 %, vegetables and fruits by 29.5 %. A shortage of animal protein, vitamins, macro- and microelements is a permanent negative factor that leads to the decrease in the body's resistance to diseases and adverse environmental factors of the environment [1].

That is why of a special relevance today is the need for improvement of technologies of traditional food products and creation of products of a new generation with a balanced composition, reduced energy and increased biological value.

A promising direction in the creation of qualitatively new food products is the combination of raw dairy with plant materials. This provides for a potential possibility for mutual enrichment of the received products by essential ingredients. The combination allows improving nutritional and biological value, as well as adjust the composition of the obtained products in accordance with the basic principles of rational nutrition [2, 3].

Plant proteins in the combination with those of animal origin create biologically active amino acid complexes. This provides their physiological validity and high digestibility [3]. The use of pectin containing vegetable raw materials provides dairy-vegetable system with new properties of stabilizing nature.

2. Literature review and problem statement

The principal provisions of the modern theory of creation of combined products have been developed by many researchers. Discussions and detailed literature reviews were also dedicated to this issue [1–9]. It was proven [7–9] that the use of vegetable raw materials in the technology of extrusion products, soft cheese and special food products increases the content of water-soluble vitamins, mineral substances, improving the taste and consumer properties.

Paper [10] argues that the combined food products must meet the following requirements: increased biological value and balance of component composition, manufacturability, affordability and cheapness of raw materials in their production, stability when stored. In addition, in the course of design of combined products, a significant role is played by medico-biological aspects and peculiarities of the effect of new types of foodstuffs on the human body. A quantitative content of formulation components of the combined products is necessary to define with regard to the equivalence of biological value of substituting raw materials.

Combined with vegetable or animal raw material, it is such a milk product in which the share of the milk base is not less than 50 %; the share of the vegetable component in the combined product must not exceed 30 % [6].

As a dairy base in the technology of combined minces they traditionally use sour cheese, which is a protein sour milk product that is made of pasteurized normalized or skimmed milk, acidified with pure cultures of lactic acid microorganisms, with a consequent separation of milk whey from the received curd and pressing out of protein mass [11]. However, traditional production technology of sour cheese allows using only the casein fraction of milk proteins. A group of whey protein that makes up 20...30 % of the total amount of protein in milk, is removed along with the serum when making sour cheese in the traditional way [11]. That is why the most promising raw material for use in the technology of dairy-vegetable minces is considered to be milk-protein concentrate (MPC) from buttermilk. This is a product of homogeneous, gentle, buttering consistence. It has a clean taste and aroma, characteristic for dairy products, without any extra after-tastes and smells, and its color is from white to white with a cream shade.

The proteins of milk protein concentrate from buttermilk contain in their composition, in addition to casein, serum proteins, the amount of which is 26 % of the mass of protein. A special feature of the protein composition from buttermilk is the presence of proteins of membranes of fat globules (55 % of their content in membranes) that pass to buttermilk due to physic-chemical and mechanical impact on the cream in the process of butter production. By their electrophoretic properties, the proteins of membranes of fat globules are identical to serum proteins. Their isoelectric point is located within pH 3,9...4,0 [12].

Studies have revealed [4] that in the composition of MPC proteins from buttermilk, the level of all essential amino acids exceed the standard of FAO/WHO [13–15], indicating a high biological value of the product.

In general, MPC is a product with a natural set of vitally important minerals [12].

The MPC from buttermilk is a good source of water-soluble vitamins, which is explained by using sour cheese serum in the production of this product, which is rich in these vitamins. It should be specially noted that there is a high content of tocopheryl (21 %) in MPC, which is involved in the processes of tissue respiration and promotes digestion of proteins and fats.

An analysis of the chemical composition of MPC from buttermilk in comparison with some milk-protein concentrates [12] revealed that by the content of dry substances, MPC from buttermilk surpasses high calcium coprecipitate by 5.6 %, low calcium coprecipitate by 9.9 %, low-fat sour cheese by 20.9 %. Protein content in MPC from buttermilk is higher than that of high calcium coprecipitate by 4.8 %, low calcium coprecipitate – 1.0 % low-fat sour cheese – 13.4 %. Compared with the mentioned concentrates of milk proteins, MPC from buttermilk have also increased fat content, as well as ash elements.

To provide mincing products with the necessary consistence and to control their rheological properties, the structure-formers are introduced to them. Promising is the use of natural structure-formers, especially high-molecular polymers (pectin, carrageenan, proteins of vegetable and animal origin, starches, etc.) that have a wide set of technological properties, high efficiency, high moisture-binding capacity. The above said confirms the feasibility of the use of vegetable raw materials in the technologies of milk-vegetable minces, rich in pectin substances that will act as stabilizers and structure-formers of the structure of minces.

Among the vegetable raw materials, the highest content of pectin substances is characteristic for different root vegetables (sugar beet, fodder beet, table beet, table carrot, celery, parsley, turnip, rutabaga, radish) – from 6.4 to 30.0 % of pectin substances per dry substance, and pumpkin (pumpkin, zucchini, patisson, melon, cucumber) from 1.7 to 23.6 %. It should be noted that the root vegetables, with the exception of table carrot, along with pectin substances contain a significant amount of essential oils and glycosides or sugar (sugar beet), which limits their use in the technology of food products because of specific taste and smell. Table carrot, which is commonly used in food technology, contains 6,4...20,0 % of pectin substances per dry substance the degree of esterification of 55...58 %. Out of pumpkin varieties, the maximum content of pectin substances is characteristic of zucchini (16,5...17,6 %), slightly lower content is found in patisson (15,5...16,9 %), pumpkin – 13,5...14,4 %, the degree of esterification of pectin substances in pumpkin is about 53...58 % [16, 17].

Thus, in the technology of milk vegetable minces (MVM) it is advisable to use table carrot, zucchini and pumpkin as a source of pectin substances and other functional ingredients. The use of carrot, pumpkin and zucchini in the technology of combined mincing masses is predetermined by economic reasons due to availability and ease of obtaining the specified raw materials. In addition, the use of local resources of regions will contribute to the increase in economic efficiency of food industry and to cutting the cost of products.

Generalized data of chemical composition of the varieties of carrot, pumpkin and zucchini, districted in the forest-steppe zone of Ukraine, confirm that it is advisable to use in the MVM technology as a vegetable component: carrot of variety Chantenay, pumpkin of variety Gilea and zucchini of variety Zolotinka [18]. These crops are common in the forest-steppe zone, gathering them is not difficult and doesn not requires any significant expenditures.

Substituting part of the raw materials of animal origin with the vegetable would reduce the calorie content of foods. In addition, we should note a very important physiological phenomenon [19]: when proteins of different origin in the composition of food rations are combined, their digestibility almost always improves that was confirmed by many researchers on the example of meat and fish, meat and dairy, as well as meat-, fish- and dairy-vegetable systems [3–6].

Since there is a contradiction between the seasonal gathering and the necessity to consume vegetables all year round, while carrot, pumpkin and zucchini are exposed to spoilage during storage and lose their initial quality, it is most appropriate to process them into semi-finished products or finished products in the season of gathering [20].

Paper [20] proved that the vegetable raw materials in the milk-vegetable compositions are rational to be used as a puree.

Introduction of vegetable raw materials to the composition of milk-vegetable minces in the form of puree provides the possibility to give mincing products necessary consistence and to adjust their structural-mechanical characteristics [21]. That is why the use of vegetable raw materials in the technology of milk-vegetable minces should be considered from the perspective of implementation of the properties of pectin substances, namely the possibility to increase the viscosity of dispersion medium and to act as a structure stabilizer. This can be achieved by the thermal treatment (TT) of vegetables and their mechanical shredding, resulting in the transition of protopectin to the soluble pectin (SP) [21, 22].

Of significant theoretical and practical interest is the development of technologies of the activation of pectin contained in vegetable raw materials by alkaline, acid or enzymatic hydrolysis of protopectin and the transfer of pectin to active state [23, 24].

In order to increase the amount of pectin substances in vegetable raw materials, a new method of preparation of carrot and pumpkin puree is proposed. The peculiarity of their obtaining is in the process of hydrolytic cleavage of protopectin of plant tissue. In the process of hydrolysis, the amount of low esterified pectin increases by almost 3 times. In addition, vegetable purees have an increased amount of fiber, beta carotene [24].

However, the above described methods of obtaining vegetable puree require correction in accordance with the selected items of the study. That is why the development of method for obtaining puree from vegetables, that provides maximum transition of pectin into active state is the dominant direction for further research.

3. Aim and objectives of the study

The aim of the work is to substantiate scientifically and confirm experimentally technological parameters of the treatment of pectin containing raw materials to ensure realization of their target properties as a structure-forming agent in the technology of milk-vegetable minces.

To achieve the set aim, the following tasks were solved:

– to determine the effect of temperature and duration of the thermal treatment of vegetable raw materials on the content of soluble pectin;

– to substantiate the method of hydrolysis of protopectin to soluble pectin;

– to develop a technological scheme of obtaining puree from carrot or pumpkin or zucchini with specified functional and technological properties.

4. Materials and methods of research

The objects of the research were identified as follows: vegetable raw materials (table carrot, variety Chantenay, table pumpkin, variety Gilea, zucchini, variety Zolotinka (Fig. 1, *a*–*c*), puree from carrot, pumpkin, zucchini).

a *b* *c*

Fig. 1. Experimental samples:
a — table carrot, variety Chantenay;
b — table pumpkin, variety Gilea;
c — zucchini, variety Zolotinka

The methods of research can be found in paper [25].

5. Results of the research into technological parameters of the treatment of vegetable raw materials to ensure implementation of their targeted properties as a structure-forming agent

Technological parameters and the modes of obtaining puree from vegetables should be considered both from the position of implementation of properties of pectin substances, namely, the ability to increase viscosity of the dispersion medium and to act as a stabilizer of the structure, and from the position of maximum preservation of low molecular biologically active substantial and other nutrients.

For the scientific substantiation of technological parameters and modes of obtaining puree from carrot, variety Chantenay; pumpkin, variety Gilea; and zucchini, variety Zolotinka, with the purpose of their further use in the technology of milk-vegetable minces, we performed a series of experimental research. The following parameters of correcting the process of obtaining puree from vegetables were selected: values of indicators of temperature and duration of TT of vegetables, temperature of shredding the vegetables, temperature and duration of TT of puree, pH of the medium.

It is known that any kind of treating vegetable raw materials may cause the start of various fermentative and non-fermentative reactions that may lead to change in the structure, nutritious and biological values, organoleptic parameters of the raw materials [23]. The basic changes include the decay of ascorbic, citric and other organic acids, oxidative and other changes in the complex of polyphenolic compounds, reactions of melanoidin-formation and caramelization, iron oxidation, change in the content of vitamins, etc. Thus, in the course of thermal treatment of vegetable raw materials there is significant loss of the vitamin C that is related to its oxidation and destruction under the influence of high temperatures. The loss of the vitamin C increases also during slowing down the technological process.

Preservation of the vitamin C is promoted by the reduction of pH of the medium and lack of catalysts-enzymes. To prevent significant destruction of the vitamin C and other biologically active substances at the beginning of the technological process, it is necessary to carry out the inactivation of oxidases by blanching or sulphitation [23].

We consider carrying out of sulphitation of vegetable raw materials inappropriate because under these conditions there is a destruction of the vitamin B_1 and a decoloration of vegetable raw materials, which is the result of interaction between sulfurous acid and coloring substances, including anthocyanins.

Paper [23] confirmed that blanching (a short-term thermal treatment with water or steam) leads to losses of the vitamin C compared to conventional thermal treatment. That is why in order to prevent significant destruction of the vitamin C from the effect of technological factors on vegetables, it is expedient to carry out the inactivation of oxidases in the composition of vegetable raw materials by thermal treatment of vegetables with steam at temperature 108...112 °C.

The substantiation of technological parameters and modes of obtaining puree from vegetables was carried out in the following way. At the first stage, we determined impact of the duration of thermal treatment of carrot, pumpkin and zucchini on the content of soluble pectin, at the second stage – the effect of temperature of the shredding of vegetables on the content of soluble pectin, at the third stage – the influence of temperature and duration of thermal treatment of puree from vegetables on the content of soluble pectin, at the fourth stage – the impact of pH of the medium on the content of soluble pectin in puree from vegetables.

We determined the effect of the duration of thermal treatment with steam without the use of additional intensifying factors on the content of soluble pectin. The vegetables were inspected, washed, cleaned, cut into cubes with rib size $l=(0,8...1)\cdot10^{-2}$ m and were exposed to the thermal treatment with steam at temperature 108...112°C [23]. Results of the research into effect of the duration of TT of vegetables on their SP content are presented in Fig. 2.

The process of accumulation of soluble pectin can be intensified by shredding the vegetables after TT [24]. It is known that for obtaining puree-like products, the vegetables are supposed to be ground after blanching in the machine for fine grinding of cooked vegetables down to the size $(2...8)\cdot10^{-3}$ m with their further homogenization to the sizes $(5...7)\cdot10^{-4}$ m and less [23]. Results of the research into the influence of temperature of shredding the vegetables on their content of SP are displayed in Fig. 3.

It is possible to intensify the rate of accumulation of pectins through the secondary thermal treatment of shredded vegetables. It is known that temperature regime over 80 °C leads to the destruction of biologically active substances of puree and has a negative impact on their nutritional value, and at temperature below 70 °C, the coagulation of proteins occurs not fully and the destruction of cell wall polymers takes place, which limits the penetration of hydrolytic factor [24]. That is why we determined the impact of the duration of heating the puree from vegetables on the content of soluble pectin at 70...80 °C. Results of the research are shown in Fig. 4.

Based on the conducted analysis of the methods of production of puree and pastes from vegetables [23], we established that the hydrolysis of protopectin most intensively occurs in the acidic medium. Correction of pH is possible by the introduction of food acids: citric acid or its mixture with ascorbic acid, phosphoric acid, etc. The most popular is the citric acid that is able to shift pH to the acidic side and additionally allows reducing the loss of β-carotene in the product, which is due to its oxidation. That is why the regulation of pH in the chosen area was carried out by the introduction of citric acid.

Results of research into the influence of pH of the medium on the SP content in the puree from vegetables are displayed in Fig. 5.

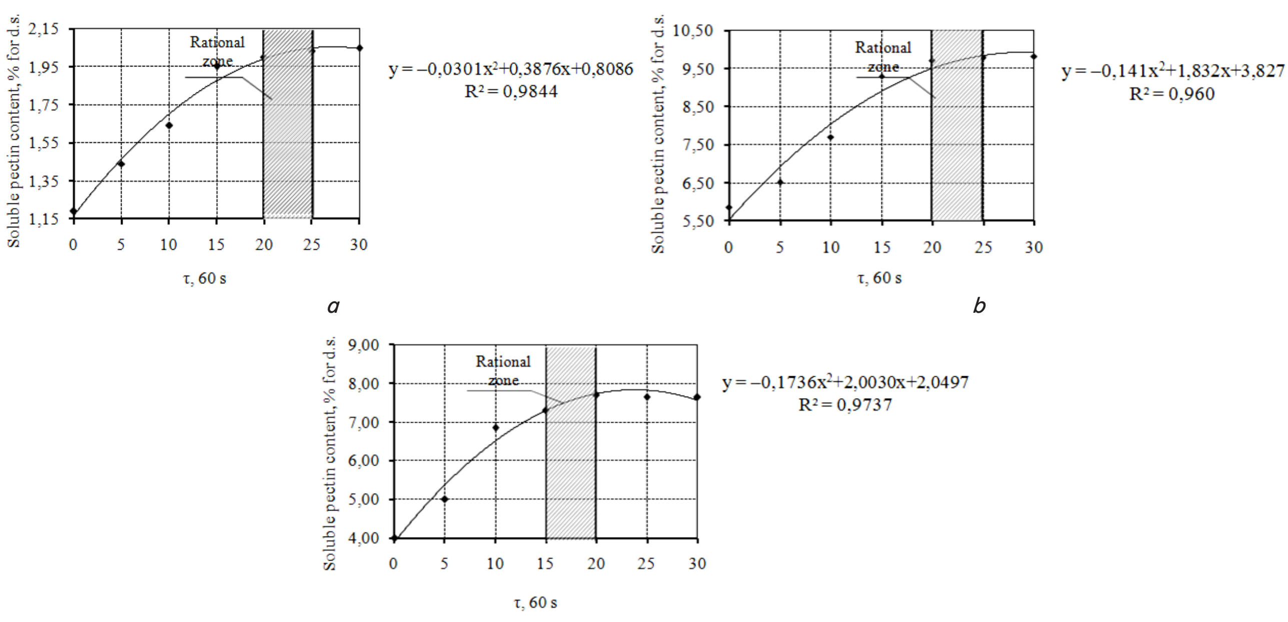

Fig. 2. Effect of the duration of thermal treatment of vegetables on the content of soluble pectin: *a* – carrot, *b* – pumpkin, *c* – zucchini

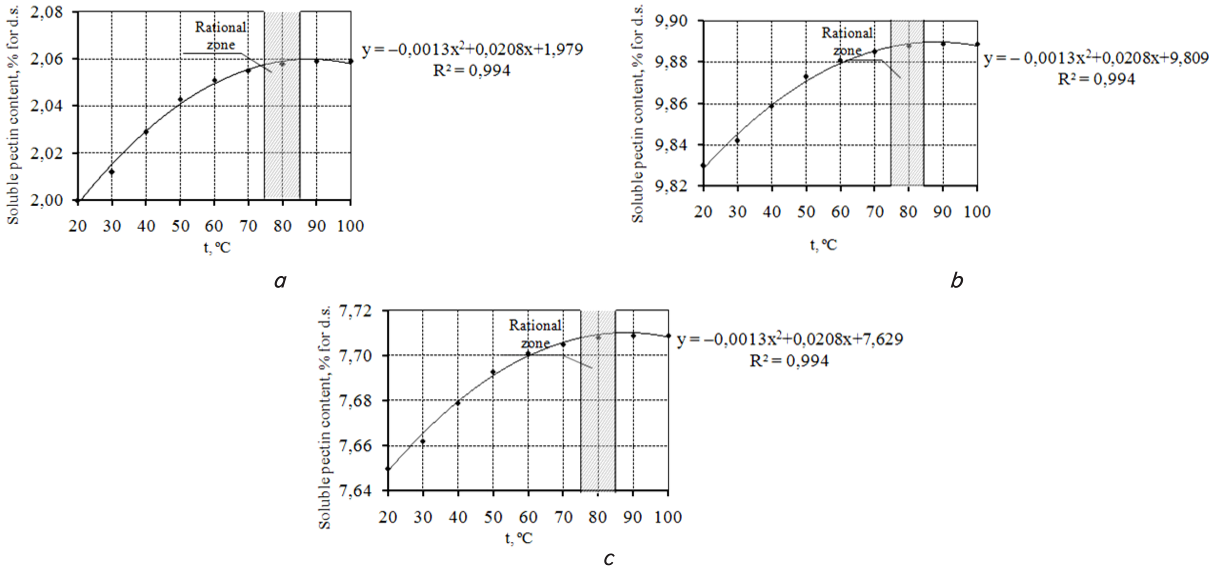

Fig. 3. Influence of temperature of shredding the vegetables on their content of soluble pectin: *a* – carrots, *b* – pumpkin, *c* – zucchini

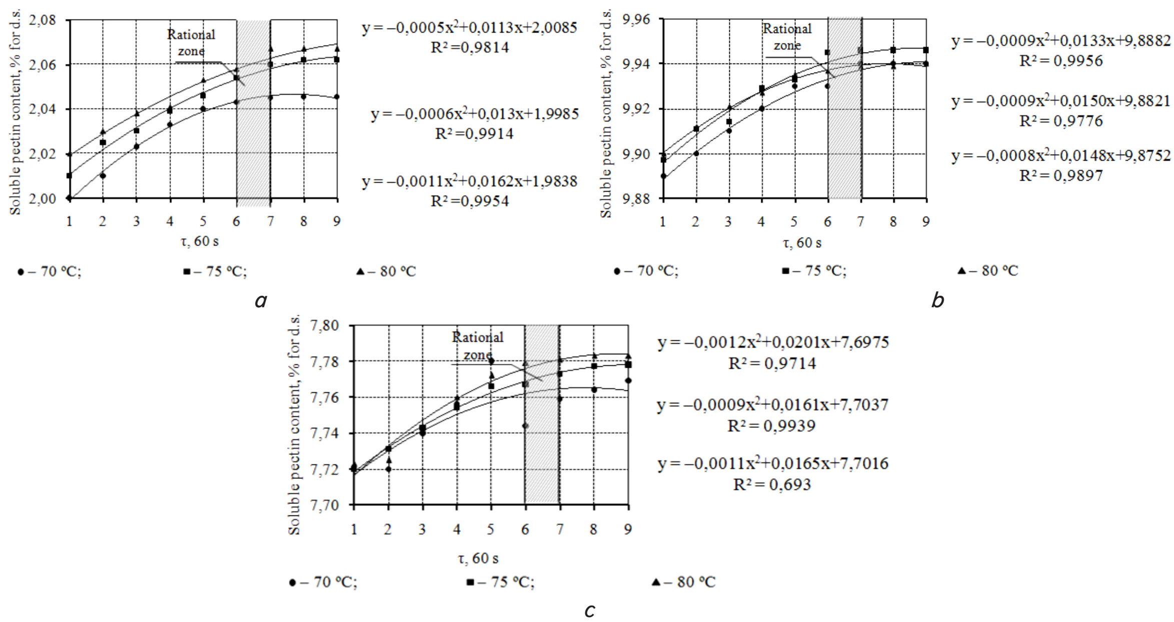

Fig. 4. Influence of temperature and duration of the thermal treatment of puree from vegetables on the content of soluble pectin: *a* – puree from carrot, *b* – pumpkin puree, *c* – puree from zucchini

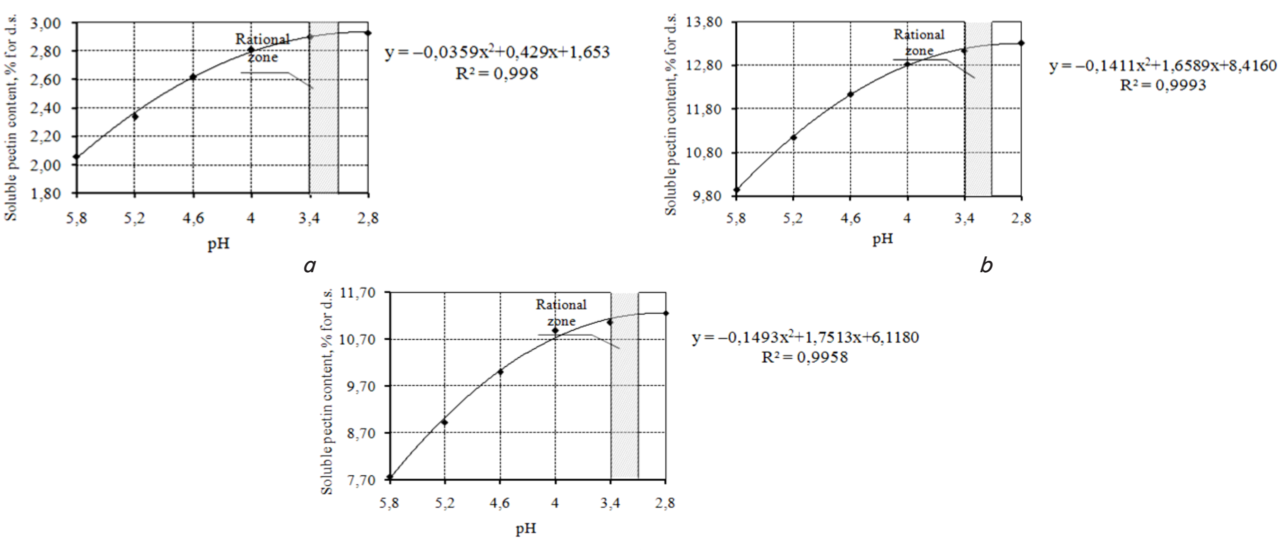

Fig. 5. Effect of pH of the medium on the content of soluble pectin in the puree from vegetables: *a* – puree from carrot, *b* – puree from pumpkin, *c* – puree from zucchini

The results obtained (Fig. 5) indicate that the change in pH significantly affects the content of SP in the puree from vegetables. Results of the research have confirmed that the maximum amount of soluble pectin in puree is accumulated at the PH values of 3,0...3,4.

6. Discussion of results of the research into technological parameters of treatment of vegetable raw materials

The results of research into the influence of the TT duration of vegetables on their SP content (Fig. 2) indicate that the maximum amount of SP is observed in (20...25)·60 s for carrot and pumpkin and in (15...20)·60 s for zucchini. The content of SP under such circumstances is: in carrot – 2.03 % for d.s. against 1.17 % for d.s. in fresh carrot, in pumpkin – 9.83 % for d.s. against 5.83 % for d.s. in fresh pumpkin, in zucchini – 7.65 % for d.s. against 4.00 % for d.s. in fresh zucchini. It is likely that under these conditions, to increase the rate of SP accumulation, additional factors of intensification are required.

It was established (Fig. 3) that the SP content reaches maximum values at the temperature of shredding of vegetables 75...85 °C, at which the destruction of bonds between pectin substances and other substances of cell walls occurs, but when applying lower temperatures, only the tissue maceration occurs.

It was revealed (Fig. 4) that a repeated TT of puree from vegetables leads to the increase in their SP content. However, the duration of TT of puree from vegetables longer that 7·60 s is accompanied by a significant decrease in the moisture content of puree and deterioration in the organoleptic indicators, in particular color of the puree from carrot and pumpkin, which probably occurs as a result of the destruction of coloring substances – β-carotene. That is why, under the above described conditions, a rational duration of TT that provides for the maximum growth in the SP content of puree while maintaining its quality indicators is (6...7)·60 s.

It should be noted that a more intensive accumulation of water-soluble pectin is observed in zucchini, which can be explained by the low degree of esterification of its pectins (about 40 %) and the course of the process of destruction of protopectin mainly due to the ion-exchange processes.

It was found (Fig. 5) that the rational value of pH for the transfer of protopectin to soluble pectin and preservation of quality indicators of puree from vegetables is 3,0...3,4. The content of soluble pectin under such conditions is 2,90...2,92 % for d.s., 13,13...13,21 % for d.s., 11,06...11,13 % for d.s. for puree from carrot, puree from pumpkin and puree from zucchini, respectively. Further reduction of pH results in insignificant changes in the content of soluble pectin and an increase in the acidity of puree from vegetables, which worsens their organoleptic indicators and quality.

Thus, based on the conducted studies, we identified the following technological parameters and modes of obtaining puree from vegetables: the temperature of TT of vegetables – 108...112 °C, TT duration – (20...25)·60 s for carrot and pumpkin and (15...20)·60 s – for zucchini, temperature of shredding of vegetables – 75...80 °C, TT temperature of puree – 75±5 °C, TT duration – (6...7)·60 s and pH of the medium – 3,0...3,4. Technological scheme of obtaining puree from vegetables is presented in Fig. 6.

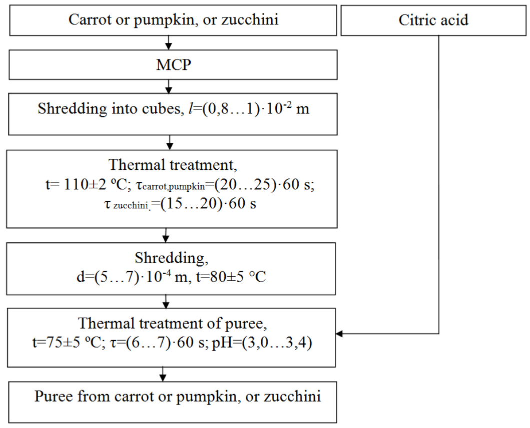

Fig. 6. Technological scheme of obtaining puree from carrot or pumpkin, or zucchini

The procedure of obtaining puree from vegetables is as follows. Carrot of the Chantenay variety, pumpkin of the Gilea variety or zucchini of the Zolotinka variety are inspected, washed and peeled, shredded in cubes with rib size l=(0,8...1)·10^{-2} m and are exposed to TP with steam at temperature t=108...112 °C for τ=(20...25)·60 s – for carrot and pumpkin and (15...20)·60 s – for zucchini. The vegetables are shredded at temperature t=75...85 °C to the size d=(5...7)×10^{-4} m. TT of puree is carried out at temperature t=70...80 °C for τ=(6...7)·60 s at pH of the medium – 3,0...3,4. Puree from vegetables, received by the proposed techniques, has buttering consistence that does not stratify during storage and consequent usage. Accumulation of soluble pectin, which displays the properties of a structure stabilizer and increases viscosity of puree from vegetables, predetermines the expediency of their use in the technology of MVM.

7. Conclusions

1. We substantiated technological parameters for treatment of vegetable raw materials to ensure the realization of their target properties as a structure-forming agent in the technology of milk-vegetable minces: temperature of TT of vegetables – 110±2 °C, duration of TT of vegetables (20...25)·60 s for carrot and pumpkin, and (15...20)·60 s – for zucchini.

2. The expediency of applying acid hydrolysis using citric acid as a pH regulator was substantiated.

3. We designed a technological scheme of obtaining puree from carrot or pumpkin or zucchini: temperature of the shredding of vegetables – 80±5 °C, temperature of TT of puree – 75±5 °C, duration of TT – (6...7)·60 s and pH of the medium – 3,0...3,4

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