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INVESTIGATION OF CHANGES OF THE SOFT BODY OF FRESHWATER MUSSELS UNDER INFLUENCE OF THERMAL PROCESSING IN THE TECHNOLOGY OF BOILED-FROZEN SEMI-FINISHED PRODUCT

Визначено вологоутримуючу здатність та рН двостулкових прісноводних молюсків роду Anodonta півночі України. Проведено дослідження динаміки змін білка, вологи, маси, а також вплив зміни ступеня пенетрації м'якого тіла прісноводних молюсків роду Anodonta в процесі термічної обробки на органолептичні властивості напівфабрикату з його використанням. На основі отриманих даних обґрунтовано технологію напівфабрикату варено-замороженого.

Ключові слова: прісноводні двостулкові молюски роду Anodonta, ступінь пенетрації м'якого тіла, напівфабрикат варено-заморожений.

1. Introduction

Investigating the relevance of the introduction of food products made from the soft body of genus Anodonta mussels, a number of significant factors are investigated. First of all, the Ukrainian market of sea delicacies is growing, while the market situation is unstable: many brands, producers, varieties of products. Consumer awareness and information is extremely low. But the demand for marine delicacies, in particular for boiled-frozen and canned mussels is constantly increasing.

Consumers of mussel products are food organizations such as cafes and restaurants and urban residents aged 30–50 years who have medium and high levels of income. For them, the product has the status of delicacy. There are not so many regular consumers of this product in Ukraine, however, demand is growing. Thus, there is a large market segment that is free of competition and has a significant capacity. A similar tendency to consumption is observed in other countries, which is confirmed by research scientists [1].

The analysis shows that, despite the growing demand for products made from mussel meat, its production remains constant. The possible reasons for this are as follows:

- lack of reliable data on mussel stocks and distribution areas of its clusters;
- an increase in the export of boiled and frozen meat of mussels by the world's leading producers of these products.

As it was proved in previous studies, the soft body of genus Anodonta mussels is a nutritious food grade with high structural and mechanical properties [2–4].

The development of new technologies for processing bivalve freshwater mussels makes it possible to in-

crease the production of quality products made from hydrobionts.

The main goals are set for the complex study of the soft body of mussels in the north of Ukraine in semi-finished product technology. It is necessary to investigate the optimal modes of technological operations, at which the structural, mechanical and organoleptic properties of the soft body, the technological losses and the duration of the technological process will be preserved to the maximum. The fulfillment of the set goals will allow increasing the competitiveness of products made from hydrobionts, which is extremely timely and economically justified task.

2. The object of research and its technological audit

The object of research is the soft body of freshwater bivalve genus Anodonta mussels and boiled-frozen semi-finished product made from freshwater mussels.

One of the most problematic places in the technology of a boiled-frozen semi-finished product made from freshwater bivalve genus Anodonta mussels is the process of thermal processing. The reason for this is a change in protein content during thermal processing, which is due to its denaturation, as well as moisture.

The soft body of freshwater bivalve genus Anodonta mussels was analyzed in laboratory conditions.

The study of the thermal processing peculiarities of the soft body of genus Anodonta mussels is carried out according to the developed model technology, shown in Fig. 1.

The most important in the technological process is temperature control and cooking time, for organoleptic, structural and mechanical properties and protein content.

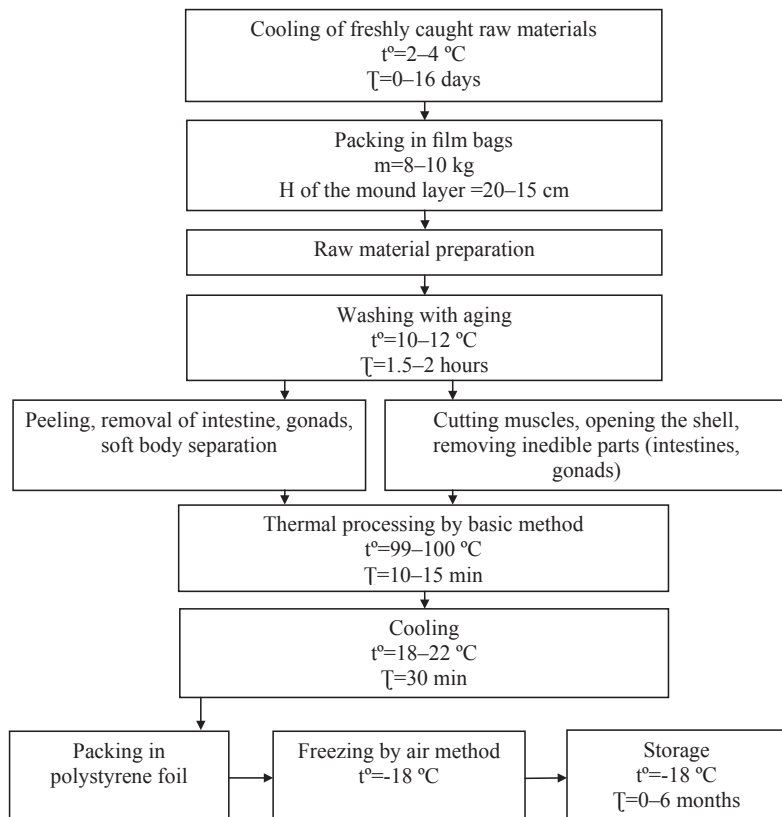


Fig. 1. Technological scheme for manufacturing a semi-finished product of a freshwater mussel

3. The aim and objectives of research

The aim of research is to determine the main structural and mechanical indicators of the raw soft body of genus *Anodonta* mussels, the dynamics of their changes in the process of thermal processing in the technology of boiled-frozen semi-finished products, the expediency of using freshwater mussels in semi-finished products and culinary products.

To achieve this aim, it is necessary to solve the following tasks:

1. To determine the dynamics of changes in protein content in the soft body of genus *Anodonta* mussels at different time intervals during the thermal processing.
2. To investigate the dynamics of changes in the mass of the soft body of genus *Anodonta* mussels at different time intervals during the thermal processing.
3. To determine the water-holding capacity (WHC) and the pH of the raw chilled soft body of genus *Anodonta* mussels.
4. To investigate changes in the penetration degree of the soft body of genus *Anodonta* mussels at different time intervals during the thermal processing.
5. To substantiate the boiled-frozen semi-finished product technology on the basis of obtained data.

4. Research of existing solutions of the problem

The change in the raw material base and the decrease in the catch of marine mussels are associated with the ecological situation [5]. This caused the need to revise

the facilities of the raw materials base for the production of semi-finished and finished culinary products, as well as to introduce changes in their production technologies. Among the main directions of the solution of the above problem identified in the resources of the world scientific periodicals, the following can be singled out:

- research of mussels (*Perna perna* mussels) as a food product in terms of physical and chemical, food and consumer properties [6];
- assessment of histopathological monitoring of *Perna perna* and Itaipu Lagoon mussels [7];
- determination of the influence of different thermal processing regimes on microbiological and organoleptic parameters of *Perna perna* mussels [8];
- the effect of thermal and various types of preprocessing (salting, pickling) on the final characteristics of mussels meat, namely the yield of the finished product and the shelf life [9].

An integrated study of the soft body of genus *Anodonta* mussels is conducted to confirm the possibility of using it as a food raw material. The amino acid composition of proteins [2], the fatty acid composition of lipids [3] and the mineral composition [4] are determined.

In the manufacture of culinary products made from hydrobionts, physical and chemical, structural and mechanical, organoleptic and other changes that affect the quality of semi-finished products and finished culinary products with their use are observed. At all stages of the technological process of manufacturing semi-finished products: catch, cooling, thermal processing, freezing, storage, optimal regimes are used, and they form the character of organoleptic, structural, mechanical and microbiological changes in the semi-finished product. A characteristic change in the heating of a soft body of mussels is the thermal denaturation of soluble protein substances and the loss of its mass, which leads to a tightening of the muscle fibers and deterioration in the consistency [10].

Technologies of semi-finished products made from freshwater mussels have not been studied industrially previously. This is due mainly to the lack of industrial technology for the cultivation and processing of freshwater aquatic organisms. That is why in the technology of the semi-finished product made from freshwater genus *Anodonta* mussels, the laws of the change in the soft body structure and the organoleptic qualities are poorly studied depending on the type of thermal processing. In addition, the soft body of freshwater mussels differs from the soft body of fish by the arrangement of myofibrils along a spiral around the fiber. In this regard, the establishment of optimal thermal cover conditions for the soft body of freshwater mussels makes it possible to prove the technology of the boiled-frozen semi-finished product. A problematic place is the uncertainty in the choice of optimal modes of the technological process, which is necessary to preserve the native properties of hydrobionts during thermal processing.

5. Methods of research

The material for research is a soft body (mantle, muscle-closer, byssus and gonads) of genus *Anodonta* mussels that are caught near the banks of the Desna River in the Sumy region in September 2016 and also boiled-frozen semi-finished product made from the freshwater mussels. Sampling for analysis is carried out according to the GOST 7631-2008 on ВЛР-200 scale (manufacturer: St. Petersburg factory «Gosmetr», Russia).

The mass loss (%) during the thermal processing of the samples is determined by weighing before and after thermal processing (after cooling to a temperature of 40 ± 2 °C).

The mass fraction of moisture in the test samples of the soft body of freshwater mussels before and after thermal processing on a Chizhov's device is determined by the formula:

$$x = \frac{m_1 - m_2}{m_1 - m} \times 100 \%, \quad (1)$$

where m – bag mass, g; m_1 – bag mass with the sample before drying, g; m_2 – bag weight with the sample after drying, g.

The water-holding capacity (WHC) in the soft body of freshwater mussels to thermal processing is determined by the Grau-Hamm method.

The penetration degree of the soft body of freshwater genus *Anodonta* mussels during thermal processing is determined using a Валента ВЦ-1 device (Russia) with a cone indenter.

pH value is determined by a potentiometric method using pH-meter pH-410 (Russia).

The total nitrogen content is determined according to DSTU ISO 5983-2003. The conversion to pure protein is carried out by multiplying by the nitrogen conversion factor for raw protein for a given product group according to the methods specified in GOST 766-85.

6. Research results

One of the main ways to prepare semi-finished products made from hydrobionts is to cook and freeze the further storage process. During a thermal processing there are processes in the tissues of mussels that lead to a change in their physico-chemical and structural-mechanical properties. Water-soluble proteins that are found in the tissues of mussels during boiling are partially secreted and mixed with the hydromodule. Also, the mass fraction of moisture is partially reduced, which leads to changes in the functional properties of the product.

To research the behavior of the soft body of freshwater mussels during the development and simulation of the formulation for semi-finished product technology, WHC and pH of the raw cooled ($t = 2-4$ °C) soft body are examined. Research results are presented in Table 1.

Table 1

Water-holding capacity (%) and pH of raw cooled soft body of freshwater genus *Anodonta* mussels $P \geq 95$ %, $n = 5$

Type of raw material	WHC	pH
Soft body of genus <i>Anodonta</i> mussels	46.3 ± 0.06	$6.6-6.7 \pm 0.02$

A soft body of freshwater mussels with low WHC indicators of 46.3 % is inexpedient to use independently in the technology of minced products. But with the use of a water-holding agent (fiber) – this is possible from the point of view of further research.

To assess the organoleptic properties of the soft body of freshwater genus *Anodonta* mussels and their relationship with the change in structural and mechanical parameters in the technological process of manufacturing semi-finished products, a gradient-based ratio is developed for the consistency ratio of the penetration degree. The scale of organoleptic consistency evaluation is given in Table 2.

Table 2

The scale of organoleptic consistency evaluation of the soft body of freshwater mussels and the penetration degree

Points	Consistency	Penetration degree, g
1	Solid, hard, considerable effort is necessary for biting	>80
2	Solid, preserves deformation	85–75
3	Plastic, well compressed by teeth	76–65
4	Soft, but a homogeneous mass is not formed during the chewing	66–55
5	Soft, well bite, homogeneous mass is formed during the chewing	<56

The organoleptic characteristics of freshwater mussels show that before the beginning of the thermal processing it is rated at 1 point, because the consistency is dense, hard, and a great effort is needed to separate the piece. At the same time, the penetration degree of the soft body of the mussels is 104.3 g. Obviously, further thermal processing of the soft body of the examined mussels will result in significant structural and mechanical changes, since thermal processing will result in loss of moisture, protein folding and WHC changes. In the technology of the semi-finished product made from the freshwater mussels, the main mode of thermal processing using the hydromodule (1:2) is chosen. Research results of the features of changes in the soft body of freshwater mussels under the influence of thermal processing, depending on its regime, are presented in Table 3.

Table 3

Change in the penetration degree of the soft body of freshwater mussels under the influence of thermal processing, depending on its term $P \geq 95$ %, $n = 5$

№ of sample	Penetration degree, g				
	Before thermal processing	5 min	10 min	15 min	20 min
1	104.3 ± 0.05	72 ± 0.05	55 ± 0.19	43 ± 0.06	69 ± 0.05
2	103.9 ± 0.09	71 ± 0.08	52 ± 0.07	44 ± 0.05	64 ± 0.21
3	101.5 ± 0.05	68 ± 0.09	48 ± 0.05	41 ± 0.12	59 ± 0.05
4	103.8 ± 0.05	71 ± 0.05	53 ± 0.05	45 ± 0.05	66 ± 0.08
5	104.9 ± 0.14	73 ± 0.05	55 ± 0.011	46 ± 0.05	65 ± 0.05

Dynamics of changes in the penetration degree and organoleptic indicators at various time periods of thermal processing of the soft body of genus *Anodonta* mussels is

characterized by an increase in the penetration degree from 104 to 68 after 5 minutes. The organoleptic evaluation achieves the highest performance – after 10–15 minutes of thermal processing by the basic method ($t=99\text{ }^{\circ}\text{C}$). Boiling for 20 or more minutes is accompanied by a sharp and abrupt change in the penetration degree and consolidation of the soft body of genus *Anodonta* mussels.

The penetration degree change of the soft body of genus *Anodonta* mussels after thermal processing is determined by the different duration of the boiling process by the basic method. Thus, for boiling time of 5 minutes, the penetration degree slightly increases, which is consistent with the organoleptic evaluation, indicating an increase in the stiffness of the tissue. 10–15 minutes of thermal processing of tissues does not significantly change the degree of its penetration, and with the duration of the process of 20 minutes – it is established a significant increase and, accordingly, the structure compaction of the tissues of mussels. With the continuation of thermal processing of the soft body of freshwater mussels, it has been established that significant changes in the structural and mechanical properties, namely, the penetration degree in the soft body of genus *Anodonta* mussels does not occur. The optimum values of boiling process duration ($t=99\text{ }^{\circ}\text{C}$) is the range from 10 to 15 minutes, which is indicated by the penetration degree which corresponds to the highest values of organoleptic evaluation – 5 points.

It has been experimentally proved that the soft body of freshwater mussels acquires the necessary state of culinary readiness in the technology of the boiled-frozen semi-finished product in 10–15 minutes of thermal processing by the main method in the presence of a hydromodule. The change in the chemical composition of the soft tissues of mussels is shown in Table 4.

Table 4

Change in the chemical composition of soft tissues of genus *Anodonta* during thermal processing $P \geq 95\%$, $n = 5$

Thermal processing duration, min.	Moisture, % (1)	Protein, %
0	78.63 ± 0.08	8.17 ± 0.11
5	73.5 ± 0.18	7.9 ± 0.12
10	67.4 ± 0.06	6.3 ± 0.11
15	65.87 ± 0.08	6.5 ± 0.14
20	50.93 ± 0.09	5.07 ± 0.11

The data of Table 4 show that the protein amount in freshwater mussels before the start of the thermal processing process is 8.17 %. After 20 minutes of boiling by the basic method, amount of protein decreases by 3.1 %. This is due to the dehydration of the soft body when exposed to high temperatures. The loss of moisture (20 minutes after the start of the boiling process) is 27.7 %. At control points (10 and 15 minutes), the protein content is almost indistinguishable and slightly decreased by 1.77 %. The

values of the protein quantity at these points are 6.3 % for 10 minutes, and 6.5 % for 15 minutes. The change in the mass fraction of moisture and protein during thermal processing is inextricably linked with the change in the mass of the raw material in relation to the semi-finished product.

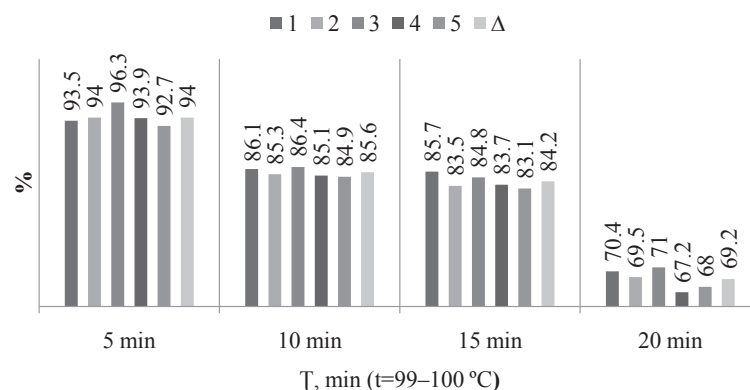
Five experiments are conducted to determine the loss of soft body mass during the processing of genus *Anodonta* mussels according to the technological scheme shown in Fig. 1 at four time control points to determine the changes in mass and the optimum time for thermal processing. The determination of the mass in the samples is carried out with cooling to a temperature of 12–14 $^{\circ}\text{C}$. The data obtained are shown in Table 5 and Fig. 2.

Loss of mass during processing of the soft body of freshwater mussels by the basic method is 30.8 % of the original value, respectively. The quantitative indicator of the mass fraction of moisture in the samples shows a difference in dehydration degree during thermal processing. Decrease in experimental samples of the soft body of genus *Anodonta* mussels within 15 minutes of heating is 15.1 %.

Table 5

Technological losses of soft body mass of genus *Anodonta* mussels during thermal processing

No of sample	Mass of samples									
	$\tau = 0\text{ min}$		$\tau = 5\text{ min}$		$\tau = 10\text{ min}$		$\tau = 15\text{ min}$		$\tau = 20\text{ min}$	
	m, g	%	m, g	%	m, g	%	m, g	%	m, g	%
1	20	100	18.7	93.5	17.2	86.1	17.1	85.7	14.0	70.4
2	25	100	23.5	94.0	21.3	85.3	21.0	83.5	17.4	69.5
3	32	100	30.8	96.3	27.6	86.4	27.0	84.8	22.7	71.0
4	23	100	21.6	93.9	19.6	85.1	19.2	83.7	15.5	67.2
5	26	100	24.1	92.7	22.1	84.9	21.6	83.1	17.7	68.0
Δ	-	100	-	94.0	-	85.6	-	84.2	-	69.2

**Fig. 2.** Technological losses of soft body mass of genus *Anodonta* mussels during thermal processing

Based on the above experimental data, the technology of a semi-finished product made from freshwater mussels is developed. The technological scheme for manufacturing a semi-finished cooked-frozen freshwater mussel is presented in detail in Fig. 1.

The technology of boiled-frozen semi-finished product includes the following stages (cooling of freshly-caught raw materials, preparation of raw materials for use in the process, thermal processing, cooling, freezing, storage).

7. SWOT analysis of research results

Strengths. Strengths of this research are related to obtaining the optimal range of parameters of the technological process of manufacturing a boiled-frozen semi-finished product made from freshwater mussels. The developed technology allows preserving high organoleptic qualities and structural and mechanical properties of raw materials. This product is much cheaper in comparison with marine analogues.

Weaknesses. The weaknesses of this research are related to the fact that this type of raw material is used for the first time in food technology. Only one of the possible directions of culinary use of the soft body of freshwater mussels has been investigated. Therefore, this work presents a narrow range of products made from hydrobionts. It is necessary to conduct a full range of studies, increase the number and time of experiments. And this will lead to an increase in material costs.

Opportunities. Additional opportunities to achieve the objectives of the study are in the great potential of this raw material in the food sense, rich in all essential nutrients and minerals. It has also been established that the structural and mechanical properties indicate that this raw material can be used not only as a boiled-frozen semi-finished product, but also as many ready-made food products.

Threats. The difficulties in implementing the developed technology are due to the fact that the use of marine analogs does not provide special conditions for production. A system for mussels growing in artificial conditions is developed for the uninterrupted supply of freshwater mussels. It is resulted in a slight increase in production costs.

8. Conclusions

1. Dynamics of changes in the protein content in the soft body of genus *Anodonta* mussels at different time intervals during the thermal processing is determined, and the obtained data are visualized using tabular and graphical methods. It is determined that the protein content before thermal processing is 8.17 %, and during the thermal processing is reduced to 5.07 %.

2. The dynamics of changes in the mass of the soft body of genus *Anodonta* mussels at different time intervals during the thermal processing is studied and obtained data are clearly presented using table and graphical methods. Mass losses during processing by the basic method for 20 minutes are respectively 30.8 % of the initial value. Within 10–15 minutes, the weight loss is 15.1 %, which is economically advantageous.

3. WHC and pH in the soft body of genus *Anodonta* mussels are determined and obtained data are clearly presented using table and graphical methods. WHC indicator is 46.3 %, pH – 6.6–6.7.

4. Changes in the penetration degree of the soft body of genus *Anodonta* mussels at different time intervals during the thermal processing are studied and the obtained data are clearly presented using tabular and graphical methods. The dynamics of changes in the penetration degree reaches the highest organoleptic characteristics after 10–15 minutes of thermal processing by the basic method at a given constant temperature $t = 99$ °C. Boiling for 20 or more minutes is accompanied by a sharp and abrupt

change in the penetration degree and consolidation of the soft body of genus *Anodonta* mussels.

5. The technology of boiled-frozen semi-finished product based on the obtained data is substantiated, the feature of which is that there is a control of temperature and cooking time for organoleptic, structural and mechanical properties and protein content in the technological process.

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ИССЛЕДОВАНИЕ ИЗМЕНЕНИЙ МЯГКОГО ТЕЛА МОЛЛЮСКОВ ПРЭСНОВОДНЫХ ПОД ВЛИЯНИЕМ ТЕРМИЧЕСКОЙ ОБРАБОТКИ В ТЕХНОЛОГИИ ПОЛУФАБРИКАТА ВАРЕНО-ЗАМОРОЖЕННОГО

Определены структурно-механические свойства двустворчатых пресноводных моллюсков рода *Anodonta* севера Украины. Проведено исследование динамики изменений белка, влаги,

массы, а также влияние изменения степени пенетрации мягкого тела пресноводных моллюсков рода *Anodonta* в процессе термической обработки на органолептические свойства полуфабриката с его использованием. На основе полученных данных обоснована технология полуфабриката варено-замороженного.

Ключевые слова: пресноводные двустворчатые моллюски рода *Anodonta*, степень пенетрации мягкого тела, полуфабрикат варено-замороженный.

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EXPERIMENTAL INVESTIGATIONS OF SUGAR CONCENTRATION FOR COUNTERFLOW JET MIXING OF DRINKS

Наведені результати експериментального дослідження процесу змішування у протитечійно-струминному змішувачі. Отримані залежності концентрації сиропу в змішаному розчині від тиску подачі води, напору купажного сиропу, величини кільцевого зазору в приймальній камері і відстані між форсунками. Визначені оптимальні конструктивно-технологічні параметри для забезпечення необхідної концентрації цукру в готовому розчині при виготовленні солодкого напою «Лимонад».

Ключові слова: струминне змішування, протитечійно-струминний змішувач, змішувач солодких напоїв, перемішування води з купажним сиропом.

1. Introduction

In Ukraine, sweet non-alcoholic drinks are in great demand. Today, in the technology of their production, there is a tendency to return to the use of natural raw materials. Previously, drinks were made on the basis of natural juices with the addition of extracts and concentrates of infusions of various collections of medicinal herbs. Thus, in the manufacture of sweet non-alcoholic drinks, one of the main processes is the mixing of fluid components.

Taking into account the growing volumes of production of sweet non-alcoholic drinks, the development and introduction of mixing devices that will ensure high-quality mixing of fluid components with minimum energy and time consumption are relevant.

2. The object of research and its technological audit

The object of this research is mixing of fluid components (in particular, water with blend syrup) in the production of sweet non-alcoholic drinks.

Depending on the method of supplying energy to the mixing medium, mixing can be pneumatic, inertial in the fluid flow, circulating, mechanical or jet [1].

Most enterprises use mechanical mixing. For this purpose, devices with a batch mixer are used. The mixing processes in such devices have been fairly well studied. There are many different designs of devices with stirrers.

Technological processes for their manufacture have been developed and their production has been established. Along with these obvious advantages, devices with stirrers have significant disadvantages. To achieve the same technological effect, these devices use more time and energy for mixing than in continuous jet mixers. If in conventional devices the residence time is calculated in minutes, then in continuous devices – in seconds. The degree and efficiency of mixing are very high due to the introduction of considerable power to a small volume.

Jet mixing is the transfer of the kinetic energy of one stream to another stream by direct contact (mixing). Increase of the pressure of the injected stream without direct consumption of mechanical energy is the main, principal property of jet devices. Due to this property, the use of such devices in many branches of production makes it possible to obtain simpler and more reliable technical solutions in comparison with the use of other mixing devices. Therefore, jet mixing was identified as the most effective and promising way of mixing fluid components.

The process of mixing fluids in counterflow-jet mixers is unexplored.

3. The aim and objectives of research

The aim of research is the experimental determination of the optimal design and technological parameters of counterflow jet mixing of water with blend syrup to obtain the required sugar concentration in the finished product.