університет, bogomolov25@gmail.com.

Bogomolov Oleksandr, PhD student Department of equipment and engineering of processing and food production, State Biotechnological University, bogomolov25@gmail.com.

Бойко Євгеній Володимирович, аспірант кафедри обладнання та інжинірингу переробних і харчових виробництв, Державний біотехнологічний університет, oipxv@ukr.net.

Boiko Evgenii, PhD student Department of equipment and engineering of processing and food production, State Biotechnological University, oipxv@ukr.net.

Науменко Едуард Миколайович, аспірант кафедри обладнання та інжинірингу переробних і харчових виробництв, Державний біотехнологічний університет, oipxv@ukr.net.

Naumenko Eduard, PhD student Department of equipment and engineering of processing and food production, State Biotechnological University, oipxv@ukr.net.

Шуваєв Микита Сіргійович, аспірант кафедри обладнання та інжинірингу переробних і харчових виробництв, Державний біотехнологічний університет, oipxv@ukr.net.

Chuvaev Mikita, PhD student Department of equipment and engineering of processing and food production, State Biotechnological University, oipxv@ukr.net.

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RESEARCH OF THE PRODUCTION PROCESS OF DRY PECTIN CONCENTRATES

G. Deinychenko, D. Dmytrevskyi, V. Chervonyi, D. Horielkov, M. Vasylenko

The expediency of membrane processing of pectin extracts in the mode with vibration mixing is substantiated. The influence of temperature, pressure and duration of the process of membrane concentration and purification of pectin extracts on the characteristics of ultrafiltration membranes of the PAN type has been established. Rational parameters and regimes of the process of ultrafiltration concentration and purification of pectin extracts have been determined.

Keywords: *pectin concentrates, membrane module, biological fluids, dry substances, pectin-containing raw materials, ultrafiltration.*

ДОСЛІДЖЕННЯ ПРОЦЕСУ ВИРОБНИЦТВА СУХИХ ПЕКТИНОВИХ КОНЦЕНТРАТІВ

Г.В. Дейниченко, Д.В. Дмитревський, В.М. Червоний, Д.В. Горєлков, М.О. Василенко

Здійснено огляд сучасних методів проведення процесів мембранної обробки пектинових екстрактів. Розглянуто питання пошуку нових технічних рішень для процесу концентрування та очищення пектинового екстракту, *визначено потрібні технічні параметри, розроблено та описано схеми технічних рішень процесу екстрагування. Проведено аналіз теоретичних та експериментальних досліджень ультрафільтраційного процесу пектинових екстрактів. За результатами проведених досліджень процесу концентрування пектинових концентратів із використанням режиму вібрації для розділення біологічних рідин установлено раціональні параметри, такі як температура, тривалість і тиск. Визначено якісні показники одержаних пектинових концентратів. Досліджено вплив ступеня попереднього розбавлення, числа циклів розчинення пектинових концентратів на продуктивність мембрани ПАН-100 в процесі його очищення діафільтрацією. Проаналізовано чинники, що впливають на рівень концентраційної поляризації на поверхні напівпроникних мембран типу ПАН у процесі ультрафільтраційного концентрування. Установлено раціональні технологічні параметри ультрафільтраційного концентрування пектинових екстрактів із використанням заходів для його інтенсифікації. Доведено, що застосування вібраційного перемішування з пульсуючими потоками пектинових екстрактів у міжмембранному каналі дозволяє інтенсифікувати процес ультрафільтраційного концентрування пектинових екстрактів порівняно з ультрафільтраційним концентруванням у тупиковому режимі в 1,5…1,6 разу. Визначено вплив ступеня та числа циклів розбавлення пектинових концентратів на продуктивність ультрафільтраційнних мембран ПАН-100 за очищення пектинових концентратів у процесі діафільтрації. Установлено фізико-хімічні показники якості кінцевого продукту – пектинового концентрату на основі пектинових екстрактів, що одержані за раціональних параметрів ультрафільтрації. Зазначено характерні несправності обладнання та способи їх усунення. Таким чином, розроблені процеси та обладнання для процесів мембранної обробки пектинових екстрактів можуть бути використані для одержання високоякісних пектинових концентратів та виробництва різноманітної кулінарної продукції на основі бурякового пектинового концентрату як на переробних, так і на спеціалізованих підприємствах харчової промисловості.*

Ключові слова: *пектинові концентрати, мембранний модуль, біологічні рідини, сухі речовини, пектиновмісна сировина, ультрафільтрація.*

Statement of the problem. One of the main directions of increasing the efficiency of modern food production is the creation of low-waste and energy-saving processes, the involvement of secondary raw materials in the food industry. The production of pectin concentrates meets this task, because, on the one hand, it allows to bring into circulation secondary pectin-containing raw materials - beetroot, apple, citrus pulp, sunflower baskets, and on the other hand, it contributes to the production of a diverse range of pectin-containing products and culinary products based on them [1]. In recent years, our country's need for pectin products (pectin concentrates) significantly exceeds the volume of their purchases abroad. To date, there is no production of pectin products. This can be explained by the imperfection and inefficiency of the existing production processes of pectin concentrates and equipment for their implementation, the lack of scientifically based resource-saving processes and technologies of pectin production [2].

The main reasons for the lack of pectin production in the food industry are the insufficient level of theoretical development of the processes of concentration and purification of pectin extracts from pectin-containing raw materials, the lack of highly efficient energy-saving equipment for pectin production [3]. The necessity of researching the processes of membrane processing of pectin concentrates has been proved, with the aim of improving the production process of pectin concentrate with its further use in the technologies of health culinary products [4].

Today, the main stages of the process of obtaining pectin concentrates that need improvement are the processes of concentration and purification of the obtained pectin extracts, which can be solved by involving baromembrane methods of processing pectin extracts [5].

Therefore, one of the urgent tasks is to improve the production process of dry pectin concentrates through the complex use of membrane methods of concentration and purification of pectin extracts, the solution of which will allow not only to create an energy-saving process for the production of pectin concentrates, but also to develop economically highly efficient equipment for its implementation [6]. And this will make it possible to introduce the obtained pectin concentrates into the development of new technologies of healthy culinary products for sale at enterprises of the restaurant industry [7].

Review of the latest research and publications. An important task of a number of branches of the processing industry is to ensure high quality of products and waste-free production [8]. To this end, the efforts of specialists and scientific employees of all branches of the national economy are aimed at creating new energy- and resource-saving technologies, waste-free processing of all constituent parts of raw materials and expanding the range of production products [9]. This fully applies to the food industry of the agro-industrial complex of the country, especially to the dairy industry. The solution to the given task is based on technologies based on particularly safe technological conditions [10]. For this, baromembrane processes have been widely used in recent years – microfiltration, ultrafiltration, reverse osmosis, etc [11]. The main feature of these membrane processing methods is the presence of a semi-permeable membrane, which has permeability according to certain dimensions of the compounds of the separated raw material [12]. Today, in the food industry, membrane processing methods are used for the purification and concentration of fruit and vegetable juices in canning production, diffusion juice in sugar production, for the concentration of milk and dairy products, stabilization of soft drinks and grape wines, plant extracts, cold pasteurization of beer, for the preparation of technological water, purification of vegetable oils, obtaining protein from potato juice, separation of the blood of slaughter animals, separation of enzymes, purification of industrial effluents, separation of gases, etc. [13].

For the food industry, the use of membrane technologies is particularly relevant, as they allow the concentration and purification of food biological fluids without the influence of temperature, preserve the native properties of food nutrients, carry out low-temperature sterilization of solutions, purify drinking water, etc [14]. Among the factors restraining the introduction of membrane methods, in particular ultrafiltration, in the food industry, it should be noted the insufficient development of theoretical provisions on the processes occurring during ultrafiltration processing of food raw materials, the lack of objective experimental data on the characteristics, properties and operating conditions of modern ultrafiltration membranes, imperfection of existing domestic industrial ultrafiltration units [15].For many years, developments were carried out to improve these processes by applying thermal, physical-mechanical, chemical, etc. methods of processing pectin extracts with the aim of obtaining an environmentally friendly product – pectin [16]. This can be observed from the information sources analyzed above. Along with this, today, membrane processes are widely used in the food, microbiological and pharmaceutical industries, and their scope of application is constantly expanding. At the same time, modern industry has at its disposal a wide range of types of membrane processes.

Thus, the study of the processes of concentration and purification of pectin extract using membrane processing processes, the study of the properties of new types of ultrafiltration membranes is an urgent task today, because it will allow to expand the introduction of ultrafiltration in the food industry, as well as to obtain pectin concentrates with high pronounced food and nutritional properties.

The objective of the research. The purpose of the article is research and improvement of the production process of dry pectin concentrates and its hardware design.

Presentation of the research material. Ultrafiltration membranes of the PAN type: PAN-50 and PAN-100 were studied in the work. PAN-type membranes are ultrafiltration membranes of the second generation, made on the basis of acronitrile copolymers. One of the main characteristics of ultrafiltration membranes is productivity. A distinction is made between the initial performance of membranes, that is, the performance of new membranes in the initial period of their operation, and the actual performance, which characterizes the operation of membranes under conditions of constant operation. To study the process of ultrafiltration concentration of pectin extracts, the main input parameters of the process were chosen: t – temperature of ultrafiltration concentration, °C; τ is the duration of the process, s^2; P is filtration pressure, MPa. Levels and intervals of variation are set for these parameters.

During the experiments, the necessary pressure in the supramembrane space of the ultrafiltration module was created using a compressor and varied from 0.2 to 0.6 MPa. The speed of the PE flow in the intermembrane channel in the vibration mode was 0.5...2.0 m/s, the feasibility of using this parameter was studied in. After 20 min, when the ultrafiltration rate became constant, the amount of filtrate that passed through the membrane in 10 min was measured. In the vibrating stirring mode, the electric motor connected to the stirrer located inside the ultrafiltration module was turned on. Dependencies of changes in performance of ultrafiltration membranes in the process of ultrafiltration concentration of pectin extracts are shown in fig. 1. Dependencies of quality characteristics of membrane processing products – pectin concentrate and permeate, obtained using the vibration mode – in fig. 2.

The results showed that the dependences of the performance of semipermeable membranes PAN-50 and PAN-100, the concentration of pectin substances in the concentrate, the content of dry substances in the permeate and concentrate under different technological regimes are non-linear. This is explained by the complexity of the combined effect of three factors of the process of ultrafiltration concentration of pectin extracts both on the productivity of the semipermeable membrane and on the quality indicators of pectin concentrates. Approximation of data by regression equations made it possible to reveal ambiguous dependences of performance of ultrafiltration membranes, concentration of pectin substances, and content of dry substances on pressure, temperature, and duration of the process of ultrafiltration concentration of pectin extracts.

From the graphical dependence of the performance of the PAN-50 and PAN-100 membranes on the ultrafiltration pressure (Fig. 1), it can be seen that the nature of the change in performance with an increase in pressure from 0.2 to 0.4 MPa in the dead-end mode shows a slow increase in productivity, and in the mode with by vibration mixing – a sharp increase in productivity for both membranes. In the area from 0.4 to 0.6 MPa, the performance of the membranes does not change significantly with increasing pressure in the dead-end mode. In the mode of vibration mixing, the performance of both membranes increases slowly with increasing pressure.

Thus, for the dead-end mode, the productivity value at P = 0,4 MPa is: for the PAN-50 membrane – 1,8 dm3/m2·h, for the PAN-100 membrane – 2,3 $dm^3/m^2 \cdot h$; at P = 0,6 MPa: for the PAN-50 membrane – 2,0 $dm^3/m^2 \cdot h$, for the PAN-100 membrane – 2,5 $dm^3/m^2 \cdot h$. In the mode of vibrating mixing with a perforated vibrating plate, the value of productivity is at

P = 0,4: for the membrane PAN – 50 – 4,1 dm³/m²·h, for the membrane PAN-100 – 4.7 dm3/m2·h; at P = 0.6 MPa: for the PAN-50 membrane – 4.5 dm³/m²·h, for the PAN-100 membrane – 5.1 dm³/m²·h. The increase in the performance of membranes under the condition of using a perforated vibrating plate can be explained by an increase in pressure (by approximately 1 MPa) over the membrane surface due to flows directed in the direction of movement of the vibrating disk to the membrane surface.

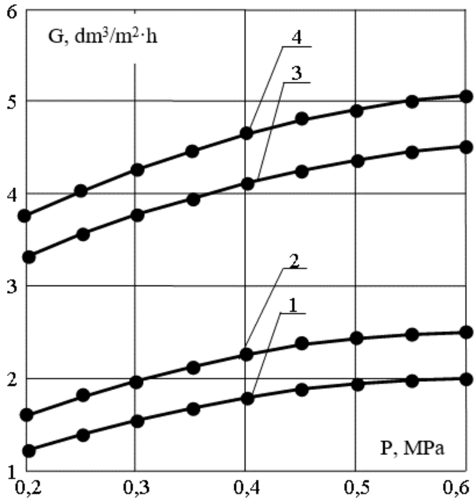

Fig. 1. Dependence of the productivity of ultrafiltration membranes of the PAN type on pressure during ultrafiltration concentration of pectin extracts at a temperature of 50ºC: 1, 3 – PAN-50 membrane in the dead-end mode and in the mode with vibration mixing, respectively; 2, 4 – the PAN-100 membrane in the dead-end mode and in the mode with vibrational mixing, respectively, the pressure in the case of the dead-end mode and the mode with vibrational mixing of the ultrafiltration concentration process is different

The analysis of the obtained data shows that increasing the pressure during ultrafiltration concentration of pectin extracts more than 0.4...0.5 MPa is impractical, because it is not impractical, because it does not lead to a significant increase in the productivity of both types of membranes. In addition, the use of a vibrating perforated disc allows not only to significantly increase the performance of ultrafiltration membranes by preventing the formation of a gel layer on their surface, but also to reduce the working pressure in the pressure channel of the ultrafiltration module.

The graphical dependence of the influence of the temperature of pectin extracts on the performance of semipermeable membranes of the PAN type

(Fig. 2) shows the difference in the curves for both regimes. At the same time, with an increase in temperature in the dead-end mode and the turbulence mode, an increase in productivity is observed for both types of investigated membranes.

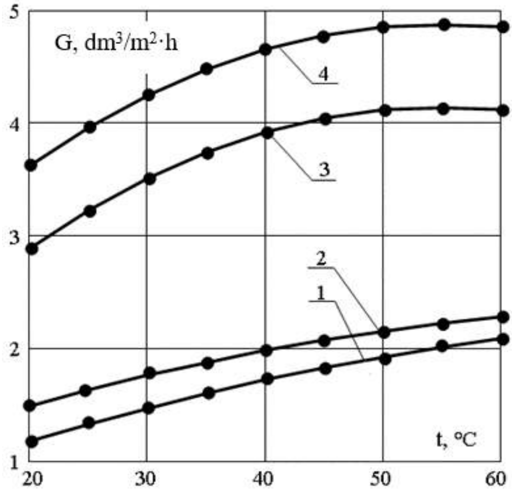

Fig. 2. Dependence of the productivity of ultrafiltration membranes of the PAN type on temperature during ultrafiltration concentration of pectin extracts at a pressure of 0.4 MPa: 1, 3 – PAN-50 membrane in the dead-end mode and in the mode with vibration mixing, respectively; 2, 4 – PAN-100 membrane in the dead-end mode and in the mode with vibration mixing, respectively

In the range of temperature values from 20 to 45ºC, there is an intensive increase in the productivity of semipermeable membranes of the PAN type for both regimes. With an increase in temperature from 45 to 60ºC in the case of a dead-end mode, the performance of the PAN-50 and PAN-100 membranes changes slightly and has a similar character. In the case of vibration mixing, with increasing temperature, the performance for both types of membranes becomes constant. A further increase in temperature is impractical, which is explained by the destruction of pectin substances in the extract during its ultrafiltration concentration.

Thus, for the dead-end mode, the productivity value at t = 45 ºC is: for the PAN-50 membrane – 1,7 $dm^3/m^2 \cdot h$, for the PAN-100 membrane – 2,2 dm3/m2·h; at t = 60ºC: for the PAN-50 membrane – 2,1 $dm^3/m^2 \cdot h$, for the PAN-100 membrane – 2,3 $dm3/m^2 \cdot h$. In the turbulence mode of the ultrafiltration process with a perforated vibrating plate, the productivity value at t = 45ºC is: for the PAN-50 membrane – 4,1 $dm^3/m^2 \cdot h$, for the PAN-100 membrane – 4,7 $dm^3/m^2 \cdot h$; at t = 60 ºC: for the PAN-50 membrane – 4,2 $dm^3/m^2 \cdot h$, for the PAN-100 membrane – 4,9 $dm^3/m^2 \cdot h$. The increase in the performance of semipermeable UV membranes of the PAN type with increasing temperature can be explained by the decrease in the viscosity of pectin extracts, which leads to a softening of the structure of the gel layer that forms on the surface of the membrane. The analysis of the obtained data shows that increasing the temperature of pectin extracts during their ultrafiltration concentration above 45...55°C is impractical, since there is no significant increase in the productivity of semipermeable membranes. In addition, it should be taken into account that too high temperatures lead to undesirable biochemical transformations of pectin substances and a decrease in their functional properties. According to the obtained dependence of the influence of the duration of the process of ultrafiltration concentration of pectin extracts on the productivity of semi-permeable membranes of the PAN type (Fig. 3), it can be seen that the character of the dependence curves has a distinct difference. During the deadlock mode, during the first 0,5...2,0 hours, there is a sharp decrease in the productivity of semipermeable membranes. Further ultrafiltration treatment does not lead to a significant decrease in the performance of the membranes. In the mode with vibration mixing, a slightly different pattern of changes in membrane productivity is observed depending on the duration of the ultrafiltration process of pectin extracts. At the same time, the productivity of both types of membranes also decreases, but to a much lesser extent.

Therefore, for the dead-end mode, the productivity value in the time range $\tau = 0,5...2,0 \cdot 60^2$ s decreases as follows: for the PAN-50 membrane – from 4,0 to 2.4 $dm^3/m^2 \cdot h$, for the PAN-100 membrane – from 4,7 to 2,8 $dm^3/m^2 \cdot h$; at $\tau = 4 \cdot 60^2$ s, productivity decreases: for the PAN-50 membrane – to 1,8 $dm^3/m^2 \cdot h$, for the PAN-100 membrane – to 2,2 $dm^3/m^2 \cdot h$. In the mode of vibrating mixing with a perforated vibrating plate, the productivity value in the time range $\tau = 0,5...2,0 \cdot 60^2$ s decreases as follows: for the PAN-50 membrane – from 5,7 to 4,8 dm3/m2·h, for the PAN-100 membrane – from 6,3 to 5,4 $dm^3/m^2 \cdot h$; at $\tau = 4 \cdot 60^2$ s, productivity decreases: for the PAN-50 membrane – to 4,2 $dm^3/m^2 \cdot h$, for the PAN-100 membrane – to 4,6 $dm^3/m^2 \cdot h$.

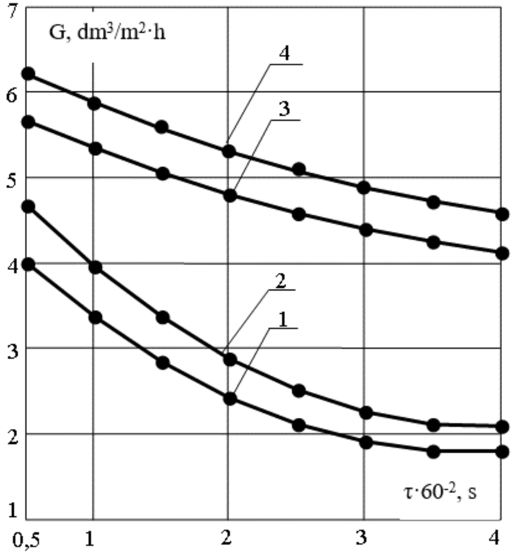

Fig. 3. Dependence of the productivity of ultrafiltration membranes of the PAN type on the duration of the process of ultrafiltration concentration of pectin extracts at a temperature of 50ºC and a pressure of 0.4 MPa: 1, 3 – PAN-50 membrane in the dead-end mode and in the mode with vibration mixing, respectively; 2, 4 – PAN-100 membrane in the dead-end mode and in the mode with vibration mixing, respectively

The decrease in the productivity of semipermeable membranes with an increase in the duration of the process can be explained by the intensive formation of a gel layer of high molecular weight substances on their surface, which significantly slows down the process of ultrafiltration concentration of pectin extracts. In the mode with vibrational mixing, the slower nature of the decrease in productivity of ultrafiltration membranes is due to the effect of vibrational turbulation on the thickness of the polarization sediment formed on their selective surface.

The conducted studies show that the rational modes of ultrafiltration concentration of pectin extract using semipermeable membranes are the following values: pressure – 0,4...0,5 MPa, temperature – 45...55 ºC, duration of the ultrafiltration concentration process – 1,5...2 hours. At the same time, the ultrafiltration concentration of pectin extracts is given significant intensity by the mode of vibration mixing, the rational values of the speed of which are in the range of 1,5...1,7 m/s.

Thus, it can be seen from the above data that the process of ultrafiltration concentration of pectin extracts using semipermeable membranes of the PAN type is complex in nature.

Conclusion. The analysis of theoretical and experimental studies of the process of ultrafiltration of pectin extracts was carried out. According to the results of the studies of the concentration process of pectin concentrates using the vibration mode for the separation of biological fluids, rational parameters were established: temperature – 40...50 ºC, duration – $(1,5...2,0)\cdot 60^2$ s and pressure – 0,4...0,5 MPa. The quality indicators of the obtained pectin concentrates were determined. The influence of the degree of preliminary dilution, the number of cycles of dissolution of pectin concentrates on the performance of the PAN-100 membrane in the process of its diafiltration purification was studied.

Thus, the developed processes and equipment for membrane processing of pectin extracts can be used to obtain high-quality pectin concentrates and produce a variety of culinary products based on beet pectin concentrate, both at processing and specialized food industry enterprises.

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Deynichenko Gregoriy, Doctor of Technical Sciences, Prof., Professor of the department of food technology in the restaurant industry State Biotechnology University, deynichenkogv@ukr.net.

Дейниченко Григорій Вікторович, д-р техн. наук, проф., професор кафедри харчових технологій в ресторанній індустрії, Державний біотехнологічний університет, deynichenkogv@ukr.net.

Dmytrevskyi Dmytro, PhD in Tech. Sc., Assoc. Prof. of the department of equipment and engineering of processing and food industries, Kharkiv State Biotechnology University, dmitrevskyidv@gmail.com.

Дмитревський Дмитро В'ячеславович, канд. техн. наук, доц., доцент кафедри обладнання та інжинірингу переробних і харчових виробництв, Державний біотехнологічний університет, dmitrevskyidv@gmail.com.

Horielkov Dmytro, PhD in Tech. Sc., Assoc. Prof., Department of

International E-commerce and Hotel and Restaurant Business, V.N. Karazin Kharkiv National University, gorelkov.dmv@gmail.com.

Горєлков Дмитро Вікторович, канд. техн. наук, доц., доцент кафедри міжнародної електронної комерції та готельно-ресторанної справи, Харківський національний університет імені В.Н. Каразіна, gorelkov.dmv@gmail.com.

Chervonyi Vitalii, PhD in Tech. Sc., Assoc. Prof., Department of International E-commerce and Hotel and Restaurant Business, V.N. Karazin Kharkiv National University, chervonyi.v@gmail.com.

Червоний Віталій Миколайович, канд. техн. наук, доц., доц. кафедри міжнародної електронної комерції та готельно-ресторанної справи, Харківський національний університет імені В.Н. Каразіна, chervonyi.v@gmail.com.

Vasylenko Mykyta, master's degree candidate, Kharkiv State Biotechnology University, mykyta.v.o@gmail.com.

Василенко Микита Олегович, здобувач вищої освіти ступеня магістра, Державний біотехнологічний університет, mykyta.v.o@gmail.com.

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ІНЖЕНЕРНІ РІШЕННЯ В ОБЛАДНАННІ ДЛЯ ВИРОБНИЦТВА ХАРЧОВОЇ ПРОДУКЦІЇ МАСОВОГО СПОЖИВАННЯ

В.М. Михайлов, А.О. Шевченко, С.В. Прасол, Б.В. Михайлов, О.І. Бабанова

У статті наведено результати роботи зі створення інженерних рішень в обладнанні для виробництва харчової продукції масового споживання. Охоплено виробництво майонезу, пастеризованого молока, вершків та ковбасних виробів. При цьому зазначається, що ключовим технічним аспектом в удосконаленні обладнання є застосування елементів автоматизації. Описано основні роботизовані системи, які входять до складу автоматизованих виробничих ліній.

Ключові слова: *технологічна лінія, обладнання, автоматизація, варені ковбаси, майонез, пастеризоване молоко, енергозбереження, електроконтактне нагрівання.*

ENGINEERING SOLUTIONS IN EQUIPMENT FOR THE PRODUCTION OF FOOD PRODUCTS FOR MASS CONSUMPTION

V. Mykhaylov, A. Shevchenko, S. Prasol, B. Mykhailov, O. Babanova

Food products for mass consumption include products that play a key role in meeting the basic physiological needs of a person in vital elements, energy and liquid. The use of these products is mandatory for a healthy diet and should be part of a daily balanced menu.

One of the main technological aspects of the production of mass