Досліджено вплив попередньої підготовки яблук та способу сушіння на якісні показники під час виробництва яблучних снеків. Встановлено, що для покращення органолептичних показників яблучних снеків доцільно проводити попередню підготовку яблук у цукровому сиропі з концентрацією цукру 40 %. З метою інтенсифікації процесу сушіння, підвищення якості готового продукту та зниження енерговитрат запропоновано комбінований конвективно-терморадіаційний спосіб енергопідведення

Ключові слова: сушіння, вологовміст, яблучні снеки, енергопідведення, пероксидаза, бланшування, цукровий сироп, конвективне, вітамін С

Исследовано влияние предварительной подготовки яблок и способа сушки на качественные показатели при производстве яблочных снеков. Установлено, что для улучшения органолептических показателей яблочных снеков целесообразно проводить предварительную подготовку яблок в сахарном сиропе с концентрацией сахара 40 %. С целью интенсификации процесса сушки, повышения качества готового продукта и снижения энергозатрат предложен комбинированный конвективно-терморадиационный способ энергоподвода

Ключевые слова: сушка, влагосодержание, яблочные снеки, энергоподвод, пероксидаза, бланширование, сахарный сироп, конвективный, витамин С

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THE USE OF CONVECTIVE-THERMORADIATIVE METHOD OF ENERGY SUPPLY IN THE APPLE SNACK TECHNOLOGY

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1. Introduction

At present, snacks, fast food that can be a light meal, are becoming increasingly popular with the population. The "snack" category includes a variety of chips, crackers, crisps, cereal flakes, dry snacks and some confectionery (biscuits, straws, special bars etc.). Main advantages of apple snacks are complete readiness to use, small size and compactness. Their distinctive features are that they are high in calories and have little moisture content. Convenient packaging, designed for one meal, makes them suitable for long-distance transportation.

Snacks, based on vegetable raw materials, are gaining special popularity in the Ukrainian market. As far as their nutritional value is concerned, these foods often leave much to be desired, because they are starch-containing and have high glycemic index. In addition, to enhance their attractiveness, manufacturers often use artificial flavors, taste and fragrance intensifiers, preservatives or a large amount of spices that excite appetite, but at the same time make these products limited in use for children, teenagers and certain population categories [1, 2]. An alternative to these products is dried apricots or raisins, put in a small package, but they usually contain residues of sulfur anhydrate after fruit sulphitation. They often require washing before use. Though common dried fruits contain certain amount of nutrients, in consumer's opinion, they are not very tasty, unattractive, that is why they do not enjoy great popularity. Candied peel consumption is also limited because Ukrainian products contain a large amount of rapidly assimilated sugars and imported products contain a lot of artificial dyes, fragrances and synthetic food additives. Therefore, there is an urgent need in the production of domestic snacks with high nutritional value based on fruit or vegetable raw materials for wide categories of the population.

Apples are widely spread and cheap raw materials for all regions of Ukraine. Their high organoleptic and technological characteristics and special features of chemical composition make these raw materials "universal" and predetermine widespread use. Thus, the production of apple snacks without using artificial food additives is relevant for the concept of healthy dieting of broad sectors of the population.

2. Literature review and problem statement

It is known that there is no a universal product. But after carrying out appropriate analyses, it is possible to predict what products and raw materials the majority of the population chooses. Apples enjoy most popularity in our region. Dried apples are used as the main component in the stewed dried fruit drinks. Direct consumption of dried apples as an independent product is limited due to not quite pronounced and not enough sweet taste, tough texture, chewing difficulty, which restricts consumer demand. These shortcomings can be avoided by producing apple snacks from peeled apples – fast food products, which do not have the above mentioned disadvantages and are characterized by high organoleptic indicators, enhanced chemical composition and high nutritive value [3].

Especially attractive for the production are winter and autumn varieties of apples that contain more than 14 % of dry matter, which is a positive factor in the process of drying. In addition, apples of autumn and winter varieties contain a significant number of substances determining their nutritional value. Sugar-acid index of such apples often exceeds 8, which is extremely appealing to the consumer [4]. Therefore, it is expedient to develop apple-based dried products for public nutrition without using artificial additives.

Different authors explored the process of obtaining apple snacks. They used traditional convective [5], microwave [6], vacuum [7], sublimation [8], and combined vacuum [9] drying and the combination of these techniques [10]. But such drying methods are quite expensive and energy-consuming. Such shortcomings can be avoided when using infrared and combined method of drying [11–13].

Under technological influences, the quality of apples deteriorates – their color changes and the vitamin complex is destroyed. To minimize this process, it is expedient to conduct their pretreatment. Scientists have already conducted research into treatment of half-finished apple products with citric acid [14], calcium salts, pasteurized milk [16], maltose syrup [15], and freezing [17]. But such treatment mainly affected only the course of drying process and structural characteristics of obtained snacks.

Since an important problem of the production of dried apple foods is a lengthy process, in particular, the stage of drying, authors of present article devoted their search to the possibilities of accelerating the process of drying due to a combination of different ways. Despite the fact that other scientists explored the possibility of obtaining apple snacks in different ways, there remain a lot of unresolved problems that prevent introducing these technologies into production. Relevant is the search for new influences on raw material with guaranteed obtaining of high quality dried product. Therefore, taking into account economic factors and capabilities of technical equipment in Ukraine, the efforts were focused on studying and researching into the possibilities of combined drying of apple raw materials by a combination of thermoradiative effect and the convective method of drying, establishing optimum conditions and parameters of the process.

3. The aim and tasks of the study

The aim of present work was to study the combined convective-thermoradiative drying of apple snacks with various pretreatment of apples. This will give an opportunity to intensify the process of drying, obtain high quality product and reduce energy consumption per unit of production.

To achieve the set aim, it was necessary to solve the following tasks:

– to select varieties of apples that are most suitable for snack production;

– to determine the optimal method of pre-treatment of apples;

– to trace the dynamics of peroxidase inactivation during apples processing;

– to establish optimal parameters for snacks drying.

4. Materials and methods of studying

The studies were conducted in 2015–2016, based on the laboratories of the Department of Technology of Preservation and the Department of Processes and Machines for Food Production at the National University of Food Technologies (Kiev, Ukraine). Modern varieties of apples, grown in Ukraine, in particular, apples of the "Champion" variety, were used in the research.

A detailed description of the plant materials that were used in the study, the method of their pre-treatment and drying, as well as the method for determining peroxidase activity and methods for determining physical-chemical indicators of snacks are presented in [18].

5. Results of research into changes in chemical composition and characteristics of apples in the course of their technological processing

5. 1. Selection of apples varieties for snacks production

Modern winter varieties of apples that are available in the Ukrainian market, such as Antonivka, Ligold, Champion, Golden, Semerenko, Renet, saffron Pepin, etc., were analyzed in the course of the study.

Among the technological indicators of raw materials, we determined organoleptic (pulp color, consistency, average size, taste, aroma, percentage of pulp and seed chamber) and physical-chemical, the most important of which was the content of solids, reducing sugars, organic acids, ascorbic acid and mineral substances. As a result of preliminary studies, apples of the Champion variety were selected.

5. 2. Peroxidase activity

The activity of enzyme system of raw materials during their processing directly affects the rate of pulp darkening after peeling and cutting apples. Among various groups of enzymes, existing in apples, the most significant for technological processing are reduction-oxidation enzymes that may lead to the deterioration of consumer values of fresh apples [19]. Of particular interest is peroxidase enzyme, which, in the presence of oxygen, oxidizes polyphenols and some aromatic amines, which leads to the deterioration of natural properties of apples. Because peroxidase activity is coherent with the activity of other enzymes, it is expedient to carry out the study of enzyme inactivation of the system with determining peroxidase activity.

The easiest way of enzymes inactivation is heating raw materials, which can be performed in different ways. The most common is heating raw materials in water or aqueous solutions, which is commonly called blanching. To preserve the integrity of pieces, blanching is carried out over short periods at temperatures 95–98 °C. During longer blanching process, there is a transition of part of protopectin into soluble pectin and significant softening of apples consistency, which is undesirable. To preserve consistency, it is proposed to carry out this process as quickly as possible with the use of sugar syrup, which slows down protopectin hydrolysis. When adding antioxidants to the composition of syrup (citric and ascorbic acid), it is possible to achieve high preservation of color in blanched raw materials.

Determining peroxidase activity was performed in the process of their blanching at temperature 95–98 °C for

2.5 minutes after every 15 seconds. If the process was prolonged, the apple pieces lost their integrity and further blanching was inappropriate. Research data are displayed in Fig. 1.

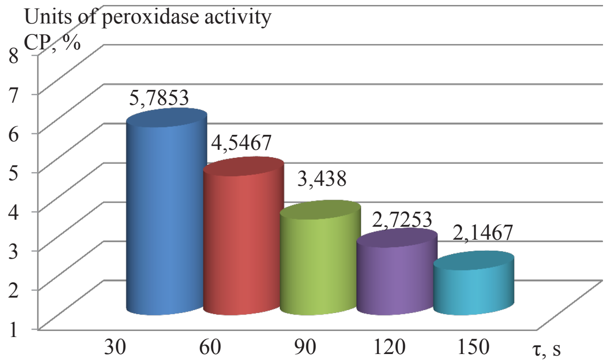


Fig. 1. Dependence of peroxidase activity on the duration of apples blanching

Fig. 1 displays direct dependence of peroxidase activity on the duration of apples blanching. We can assume that for the complete peroxidase inactivation, the duration of blanching will be around 3–3.5 minutes. But given the required consistency of apples, apples blanching within 90 seconds will be the best. The subsequent peroxidase inactivation will take place in the process of drying.

5. 3. Dynamics of sugar absorption by fruit

To establish the optimal organoleptic parameters of snacks, pre-treated apples were blanched in different concentrations of sugar syrup from 15 % to 70 % with the addition of citric and ascorbic acids. In this case, the original solids content of apples was 16.5 % and changed after blanching, depending on the concentration of sugar syrup (Fig. 2).

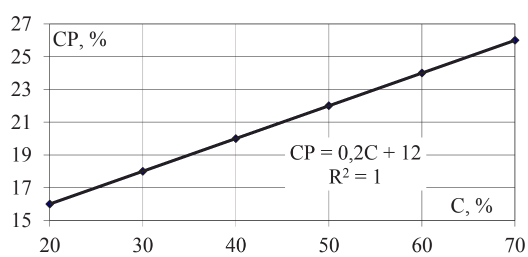


Fig. 2. Dynamics of sugar absorption by apple slices depending on the concentration of sugar syrup at blanchin

Fig. 2 displays the dynamics of sugar absorption by apple slices. All the samples were subjected to drying, but among the obtained samples, only four, which had been blanched at concentration of sugar syrup from 20 % to 50 %, had the best organoleptic indicators. Therefore, further research was carried out with these samples.

5. 4. Process of drying snacks

When using the convective-thermoradiative way of energy supply, raw materials are quickly heated. At the same time, through the application of pulsed mode, there is no overheating, which contributes to maintaining the original chemical composition of apples. Transfer of moisture from the product into environment takes place due to the difference of its content in the product and the environment, and its removal outside the chamber is performed by forcedly heated air. Complete drying of apple snacks proceeds relatively slowly for 1–1.5 hours under economical temperature modes.

Based on the obtained research data, the curves of drying were plotted (Fig. 3), which characterize the change in the integrated moisture content W^c depending on time τ.

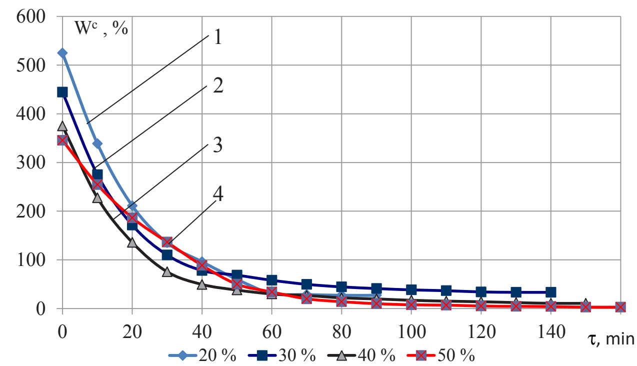


Fig. 3. Curves of combined drying of apples blanched in sugar syrup of concentration: 1– 20 %; 2 – 30 %; 3 – 40 %; 4 – 50 %

Fig. 3 shows that the period of heating for all samples is actually absent. Slowing down the moisture removal from samples is associated with an increase in the concentration of sugar and pectin substances in the liquid phase of raw materials, and in its viscosity, which adversely affects the process of drying. In addition, the processes of hydrolysis of pectin substances, which go on when heating raw materials, also lead to an increase in the share of high-molecular colloids.

Approximating data for the first period of drying by the method of least squares with the use of applied programs MatCad and MatLab, we obtained the equation of dependence of moisture content on time and concentration (1):

$$W^c=(0,01C^2-0,39C-14,7)\tau-201,4\ln C+ +1127 \text{ at } R^2=0,96, \quad (1)$$

where W^c is the moisture content, %; τ is the time, min; C is the concentration of sugar syrup when blanching, %; R^2 is the correlation coefficient

For the second period of drying, similarly we obtained the equation:

$$W^c=(0,81C^2-60,9C+ +1274)e^{(-0,000008\tau+0,0055C-0,11)\tau} \text{ at } R^2=0,90. \quad (2)$$

As a result of processing the curves of drying, we obtained dependences of the rate of drying apple pieces on the moisture content (Fig. 4), which allow us to analyze the dynamics of drying the samples.

The obtained graphs allow us to analyze three periods, characteristic for the whole process of drying – the period of heating the product, the period of constant rate of drying (horizontal lines) and the third period of decreasing rate of drying – complete drying.

While deriving the equation of kinetics of drying from experimental dependences of $dW^c/d\tau$ on W^c, it was found that at the first stage, the rate of drying can be approximately considered constant, and, starting with the second period of drying, we observe falling dependence with different characteristics at increasing the concentration of solids.

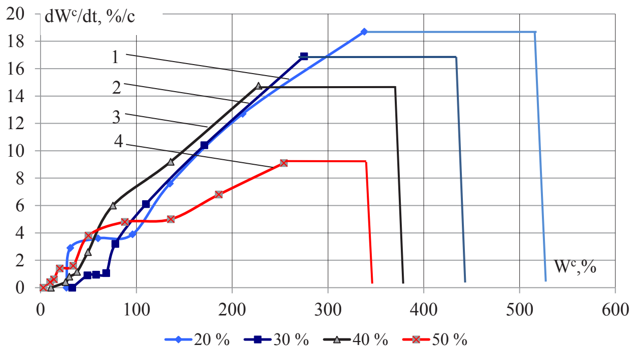
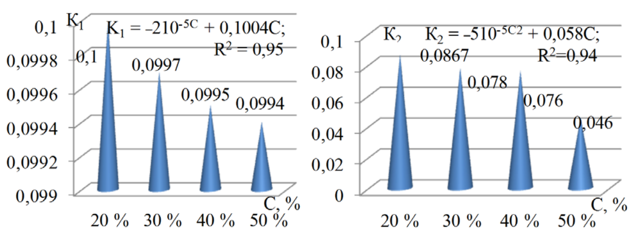


Fig. 4. Curves of rate of combined drying of apples blanched in sugar syrup of concentration: 1 – 20 %; 2 – 30 %; 3 – 40 %; 4 – 50 %

After analyzing the second period of drying, we derived the approximated equation for all samples (3):

$$dW/d\tau=(-0{,}0535C^2+0{,}7C-2{,}3)\ln(W^c)+ +0{,}0535C^2+3{,}048C-16{,}25 \text{ at } R^2=0{,}87. \quad (3)$$

Based on processing the graphs of curves of drying and drying rate, we derived dependences of coefficients of drying rate in the first and second periods and the approximating equations (Fig. 5).



a *b*

Fig. 5. Coefficients of drying rate for snacks at different concentrations of sugar syrup: *a* – in the first period of drying; *b* – in the second period of drying

When examining the periods of drying, the rate of the drying process was determined by the state of environment and conditions of drying, and full moisture flow was expressed through volumetric mass transfer coefficient (Fig. 6).

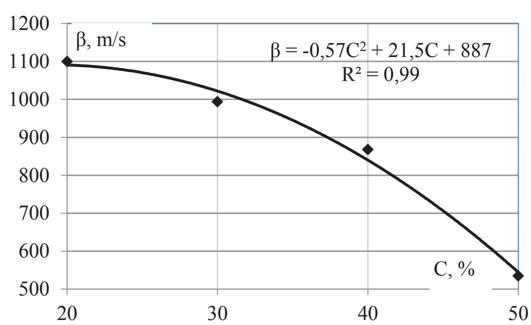


Fig. 6. Dependence of mass transfer coefficient on the concentration of sugar syrup

As a result of processing the experiment with the use of the program MathCad, we obtained dependence of the mass transfer coefficient on the concentration of sugar syrup (4) β=f(C):

$$J=dW^c/d\tau=\beta(x_P-x)=\beta(x_1-x), \quad (4)$$

where x_p is the moisture content of the air (kg/kg) at the boundary of the particle which is considered balanced; $x_p=x_1$ is the moisture content of the air at constant drying rate (first period of drying) (kg/kg), which is found by psychrometric data. Molar mass of water $M_W=18$, of air $M_P=29$, relative air humidity φ=64 %. Partial pressure of saturated vapor P at temperature t may be found from the tables, and mole fraction m – from ratio $m_1=Pt_1/(1-Pt_1)$, $Pt_1=Pt/760$. At temperature of 21 °C $Pt_{21}=18{,}66/760=0{,}025$.

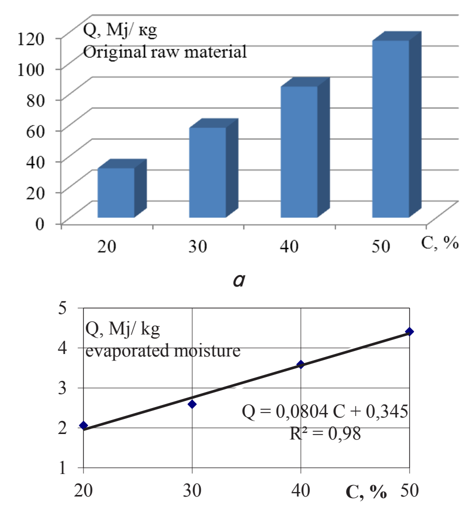
Mole fraction at 21 °C is $m_2=Pt_{21}\varphi/(1-Pt_{21})=0{,}016$. Moisture content in the first period is found according to formula (5)

$$x_1=(M_W/M_P)(m_1/(1-m_1)). \quad (5)$$

Moisture content $x=(M_W/M_P)(m_2/(1-m_2))=0{,}01$.

5. 5. Energy consumption

When processing the data of the combined drying process, we determined energy consumption for all samples of snacks in kW·h per kg of original raw material and in MJ/kg of evaporated moisture (Fig. 7).



a

b

Fig. 7. Energy consumption at different concentrations of sugar syrup: *a* – per 1 kg of original raw material; *b* – per 1 kg of evaporated moisture

Fig. 7, *a* demonstrates that the largest energy consumption was for the snacks that were blanched in the 50 % sugar syrup – 11.9 kW·h/per kg of original raw material, and the lowest – 5.9 kW·h/per kg of original raw materials for the snacks that were blanched in the 20 % sugar syrup.

Approximating data of energy consumption depending on the concentration of sugar syrup during blanching of the original raw material, we derived the equation N=20.5 C+1.35 at $R^2=0.97$; where C, % is the concentration of sugar syrup during blanching apple snacks.

5. 6. Quality indicators of snacks

After drying, the sample snacks are left for 2–4 hours for maturing, removal of the sticky layer from the snack surface, and their complete drying in the air.

Peroxidase activity was determined in ready snacks. In the process of drying it decreased to 0.36 units of activity per 1 g of product.

As organoleptic properties remain the main criterion for the production and selling of food products, we studied the organoleptic parameters of obtained snacks samples and made their taste assessment. In this case, the following indicators were taken into account: characteristic color, fragrance, ease of chewing and aftertaste. The samples of snacks, which were produced with the use of sugar syrup of 30 %, 40 % and 50 % concentrations, scored most. The overall assessment of these samples was high, and the difference in scores between them was insignificant. For final determination of the product, an analysis of the food value of the obtained samples by their chemical composition was carried out. The sample of apples, dried with the use of the combined method, was chosen as control for comparison (Table 1).

Table 1

Chemical composition of apples and snacks, obtained in different ways

Indicator	Apples (edible part)		Snacks, processed in syrup with sugar concentration, %				
	fresh	dried	30	40	50	60	70
Dry substances of apples, %	13,75	80	13,75	13,75	13,75	13,75	13,75
Mono- and bi-sugars, %	10,2	61,0	62,0	64,1	66,1	67,9	69,0
Organic acids, %	0,5	2,4	2,2	2,0	1,7	1,6	1,4
Pectin substances, %	1,0	4,8	4,4	4,0	3,5	3,0	2,8
Dietary fiber, %	0,9	4,3	4,0	3,6	3,2	3,0	2,6
Mineral substances, %	0,7	3,3	3,1	2,8	2,5	9,0	2,1
Vitamin C, mg %	3,5	2,7	4,9	6,9	7,6	8,4	8,9

As it can be seen from Table 1, with an increase in the concentration of sugar syrup with pre-treatment of apples, the nutritional value is decreased due to the growth in the content of mono- and bi-sugars in the finished product and due to a decrease in other substances, which determine the nutritional value of the product.

With a comprehensive approach to evaluation of quality of the obtained products, taking into account results of the tasting assessment, food value, possibility of decreasing the time of drying process and decreasing energy consumption, it is possible to recommend the apple snacks for the production with processing apples of the Champion variety in sugar syrup of 40 % concentration.

6. Discussion of the outcomes of the study

During the selection of apples varieties for snacks production, those that contained large amounts of dietary fiber and protopectin appeared to be the best. These substances provide for necessary elastic structure within the whole technological process both at blanching and drying.

At the same time, a high content of sugars (14 %) and organic acids (0.5 %) provide for the necessary sugar-acid indicators.

Soft modes of technological processing of apples result into minimal losses of nutrients, but at the same time provide for the inactivation of enzyme systems of fruit. Additional introduction of ascorbic acid during blanching leads to the vitaminization of the finished product. As a result, we obtain a product with an appropriate structure, fairly easy to consume, and having high organoleptic indicators, in the first place, taste.

An application of combined convective-thermoradiative drying of apple snacks contributes to electricity savings, accelerating of technological process and thus to preserving biologically active substances.

The benefits of these studies include the use of the designed experimental-industrial drying plant, which allows carrying out wide-range research directly in the process of drying. In this case, the experimenter has the possibility to change the temperature, air motion velocity, voltage on thermal heating elements, to set automatic pulse mode "heating-cooling", and to determine energy consumption at any moment of the drying process. In addition, there is a possibility to observe the dynamics of the process (change in mass, drying rate) directly in the chamber without removing the product (insulating it from the environment).

The disadvantages include small amount of the studied material (200 g in raw) compared with the large dimensions of the plant.

The obtained results of research can be useful for post-graduate students, scientists, technologists of food industries that are related to the production or application of fruit semi-finished products in food technologies.

The study continues previous scientific work (developments) on drying fruit and vegetable raw materials in different ways with obtaining basic dried products. The presented research implies the necessity of implementation of advanced technologies of fruit snacks, development of optimal energy-saving modes and establishing parameters for their drying. In future these studies can be extended and improved by the application of other types of vitamin-containing plant raw materials and various biologically active supplements of natural origin.

7. Conclusions

1. On the basis of the conducted studies, it is recommended to use for snacks production winter apples of the Champion variety, which is characterized by high organoleptic indicators and substantial content of dietary fiber.

2. Pre-treatment of apples includes the use of sugar syrup with the sugar concentration of 40 % and the use of citric and ascorbic acids. These measures significantly improve organoleptic indicators and contribute to the vitaminization of the product.

3. The dynamics of peroxidase inactivation in the process of apples blanching was investigated. It was found that blanching within 1.5 minutes in sugar solution of 40 % concentration with the addition of citric acid leads to a decrease in peroxidase activity by 1.8 times. Subsequent inactivation of peroxidase takes place in the process of drying and reaches 0.36 units of activity per 1 g of the product.

4. The optimal parameters of snacks drying were established, namely: the first period – in pulsed mode of heating-cooling by means of convective-thermoradiative energy supply with maintaining the temperature of 70–75 °C, the

second (complete drying) – using convective method at temperature 40–45 °C. The advantage of this method is fast heating of raw materials, but without their overheating. It promotes the preservation of the original chemical composition of apples, accelerates the drying process by 1.5 times and enables reduction in energy consumption by 25–30 %.

References

1. Strelnikov, A. Innovative approaches to processing fruit production [Text] / A. Strelnikov // Technology and Food processing industry Agribusiness – healthy food. – 2015. – Vol. 1, Issue 5. – P. 95–101.
2. Kalinina, I. V. Modern approaches to technology safe snack products [Text] / I. V. Kalinina, A. A. Ruskina // Bulletin of South Ural State University. Series: Food and Biotechnology. – 2014. – Vol. 3, Issue 2. – P. 29–36.
3. Yao, Z. Mathematical modelling and simulation of mass transfer in osmotic dehydration processes. Part I: Conceptual and mathematical models [Text] / Z. Yao, M. le Maguer // Journal of Food Engineering. – 1996. – Vol. 29, Issue 3-4. – P. 349–360. doi: 10.1016/0260-8774(95)00045-3
4. Ahmad-Qasem, M. H. Influence of Drying on the Retention of Olive Leaf Polyphenols Infused into Dried Apple [Text] / M. H. Ahmad-Qasem, J. V. Santacatalina, E. Barrajón-Catalán, V. Micol, J. A. Cárcel, J. V. García-Pérez // Food and Bioprocess Technology. – 2015. – Vol. 8, Issue 1. – P. 120–133. doi: 10.1007/s11947-014-1387-6
5. Velickova, E. Physical and sensory properties of ready to eat apple chips produced by osmo-convective drying [Text] / E. Velickova, E. Winkelhausen, S. Kuzmanova // Journal of Food Science and Technology. – 2014. – Vol. 51, Issue 12. – P. 3691–3701. doi: 10.1007/s13197-013-0950-x
6. Noorbakhsh, R. Radiant energy under vacuum (REV) technology: A novel approach for producing probiotic enriched apple snacks [Text] / R. Noorbakhsh, P. Yaghmaee, T. Durance // Journal of Functional Foods. – 2013. – Vol. 5, Issue 3. – P. 1049–1056. doi: 10.1016/j.jff.2013.02.011
7. Joshi, A. P. K. Sensory and nutritional quality of the apple snacks prepared by vacuum impregnation process [Text] / A. P. K. Joshi, H. P. V. Rupasinghe, N. L. Pitts // Journal of Food Quality. – 2010. – Vol. 33, Issue 6. – P. 758–767. doi: 10.1111/j.1745-4557.2010.00349.x
8. Hawkes, J. Osmotic concentration of fruit slices prior to freeze dehydration [Text] / J. Hawkes, J. M. Flink // Journal of Food Processing and Preservation. – 1978. – Vol. 2, Issue 4. – P. 265–284. doi: 10.1111/j.1745-4549.1978.tb00562.x
9. Bi, J. Effects of pretreatments on explosion puffing drying kinetics of apple chips [Text] / J. Bi, A. Yang, X. Liu, X. Wu, Q. Chen, Q. Wang et. al. // LWT – Food Science and Technology. – 2015 – Vol. 60, Issue 2. – P. 1136–1142. doi: 10.1016/j.lwt.2014.10.006
10. Joshi, A. P. K. Impact of drying processes on bioactive phenolics, vitamin C and antioxidant capacity of red-fleshed apple slices [Text] / A. P. K. Joshi, H. P. V. Rupasinghe, S. Khanizadeh // Journal of Food Processing and Preservation. – 2011. – Vol. 35, Issue 4. – P. 453–457. doi: 10.1111/j.1745-4549.2010.00487.x
11. Grishin, M. O. Model of drying mixed heat supply [Text] / M. O. Grishin, M. I. Pohozhyh, V. A. Potapov // Scientific works of ODAFT. – 2001. – Vol. 22. – P. 17–20.
12. Tarasenko, T. A., Evlash, V. V., Nemyrych, A. V. (). Theoretical study of methods of drying fruits and vegetables [Text] / T. A. Tarasenko, V. V. Evlash, A. V. Nemyrych // Scientific Bulletin of Lviv National University of Veterinary Medicine and Biotechnology named after S. Z. Gzhytskoho. – 2015. – Vol. 4, Issue 64. – P. 135–143.
13. Zavaliy, A. A. Infrared drying apparatus for fruit and vegetables [Text] / A. A. Zavaliy, I. V. Yanovich // Scientific works of Vinnytsia National Agrarian University. Series: Engineering. – 2012. – Vol. 11, Issue 2. – P. 347–351.
14. Doymaz, İ. Effect of citric acid and blanching pre-treatments on drying and rehydration of Amasya red apples [Text] / İ. Doymaz // Food and Bioproducts Processing. – 2010. – Vol. 88, Issues 2-3. – P. 124–132. doi: 10.1016/j.fbp.2009.09.003
15. Mišljenović, N., Poređenje kinetike osmotskog sušenja jabuke u melasi šećerne repe i rastvorima saharoze [Text] / N. Mišljenović, G. Koprivica, L. Lević // Journal on Processing and Energy in Agriculture. – 2010. – Vol. 14, Br. 1. – P. 32–35.
16. Tavera-Quiroz, M. J. Development and Characterization of a Baked Snack from Rings of Green Apples [Text] / M. J. Tavera-Quiroz, M. Urriza, A. Pinotti, N. Bertola // Food and Bioprocess Technology. – 2014. – Vol. 7, Issue 8. – P. 2218–2227. doi: 10.1007/s11947-014-1310-1
17. Tavera-Quiroz, M. J. Baked snack from green apples formulated with the addition of isomalt [Text] / M. J. Tavera-Quiroz, M. Urriza, A. Pinotti, N. Bertola // LWT – Food Science and Technology. – 2015. – Vol. 62, Issue 2. – P. 1004–1010. doi: 10.1016/j.lwt.2015.02.009
18. Malezhyk, I. The study of features of control of technological process for receiving the apple snacks [Text] / I. Malezhyk, I. Dubkovetskiy, H. Bandurenko, T. Levkivska, L. Strelchenko // EUREKA: Life Sciences. – 2016. – Vol. 6. – P. 17–23. doi: 10.21303/2504-5695.2016.00245
19. Kretovich, V. L. Fundamentals of Plant Biochemistry [Text] / V. L. Kretovich. – Moscow: Vycshaya shkola, 1971. – 464 p.