UDC 664.87

APPLICATION OF POTATO PULP IN TECHNOLOGY OF SNACKS

K. Rubanka, O. Shevchenko
National University of Food Technologies

Key words:
Potato pulp
Green buckwheat flour
Snacks
Waste-free technologies
Consumer properties

Article history:
Received 14.03.2022
Received in revised form 31.03.22
Accepted 21.04.2022

Corresponding author:
K. Rubanka
E-mail:
npnuht@ukr.net

ABSTRACT

The solution of the problem of waste-free production is one of the key tasks in the processing industry and it requires clear corrective actions. The use of waste generated by the production of potato starch in the technology of potato snacks will reduce the amount of such waste, as well as will ensure the production of snacks with pleasant taste and high consumer value.

The article presents the results of and the use of technological measures for the production of potato snacks based on pulp and green buckwheat flour. The influence of green buckwheat flour dispersion on structural and mechanical properties of dough and finished products was analyzed. It was found that to ensure the highest elasticity and softness of the dough, it is advisable to use flour with size of particles — 850 microns due to the large amount of fiber in the pulp and the passage of deeper colloidal processes due to free molecules of protein and starch in green buckwheat flour. However, taking into account the effect of flour dispersion on the strength of finished snacks, it is advisable to use flour with particle size — 670 μm, because increasing particle size of flour to 850 μm does not significantly increase the strength of finished products (only by 2.7%), bur significantly reduces the plasticity of the dough — by 26.1%, which begins to complicate the process of kneading dough and its formation. Waffle irons were used for heat treatment of the developed snacks, so the fat content in this product was only 2.2 g/100 g, and the washed starch from the pulp reduced the carbohydrate content to 45.21 g/100 g. The successful combination of raw materials and the choice of technology for the production of potato snacks allowed to develop a product which has an energy value of only 522.5 kcal per 100 g, and its glycemic index is 15.62 units. Thus, the possibility of consuming such a product by people who monitor their weight was proved. Their compliance with regulatory documentation was proved by sensorial and physicochemical analysis.

DOI: 10.24263/2225-2924-2022-28-2-12

ЗАСТОСУВАННЯ КАРТОПЛЯНОЇ МЕЗГИ У ТЕХНОЛОГІЇ СНЕКІВ

К. В. Рубанка, О. Ю. Шевченко
Національний університет харчових технологій

Проблема безвідходного виробництва є однією з ключових у переробній галузі і вимагає чітких коригувальних дій для її вирішення. Використання відходів, що утворюються у результаті виробництва картопляного крохмалю, в технології картопляних снеків дасть змогу знизити кількість таких відходів, а також забезпечить виробництво снеків з високими смаковими властивостями та споживчою цінністю.

У статті представлені результати застосування технологічних заходів при виробництві картопляних снеків на основі мезги та борошна із зеленої гречки. Проаналізовано вплив дисперсності борошна із зеленої гречки на структурно-механічні властивості тіста й готової продукції. Встановлено, що для забезпечення найвищої пружності та м'якості тіста доцільно використовувати борошно з крупністю 850 мкм, що пояснюється великою кількістю клітковини у меззі та перебігом більш глибоких колоїдних процесів за рахунок вільних молекул білка та крохмалю в борошні зеленої гречки. Проте, зважаючи на вплив дисперності борошна на міцність готових снеків, доцільно застосовувати борошно розміром частинок 670 мкм, оскільки підвищення розміру частинок борошна до 850 мкм не значно підвищує міцність готових виробів (всього на 2,7%), але суттєво знижує пластичність тіста — на 26,1%, що починає ускладнювати процес замісу тіста та його формування. Для термічної обробки розроблених снеків використовували вафельниці, тому вміст жиру в такому продукті складає лише 2,2 г/100г, а вимитий крохмаль з мезги знижує вміст вуглеводів до 45, 21 г/100г. Вдале поєднання сировини та вибір технології виробництва картопляних снеків дало змогу розробити продукт, який має енергетичну цінність лише 522,5 ккал з розрахунку на 100 г готового продукту, його глікемічний індекс — 15,62 од. Доведено можливість споживання такого продукту людьми, що стежать за своєю вагою. З органолептичного та фізико-хімічного аналізу доведена їх відповідність нормативній документації.

Ключові слова: *картопляна мезга, борошно із зеленої гречки, снеки, безвідходні технології, споживчі властивості.*

Formulation of the problem. During processing potatoes into starch, a mixture of by-products is obtained, which includes pulp and juice water. It was showed (Wu, 2016) that if no effective measures are taken to continue using this waste, negative economic and environmental outcomes may weaken the benefits of starch recycling, but this waste-free technology industry faces major challenges. Firstly, due to the large amount of water present in fresh waste, almost 80 percent, they are not suitable for concentration and long-term transportation, and therefore they are taken to the fields without any disposal. Due to the deterioration of organic materials and the development of bacteria, the environment can be littered with horrible odors (Levin et al., 2007). Secondly, burying the pulp leads to contamination of soil and groundwater. On the other hand, if these residues of potato waste are dried and turned into dry fodder, the cost of such waste increases significantly due to the low utilization rate (Wu, 2016).

Therefore, complex processing of potatoes with minimization of waste remains an important stage in the development of the processing industry.

Analysis of recent research and publications. Based on the data of various scientists, directions in the field of possible use of potato pulp were identified, namely:

- enrichment of pulp, which containing potato protein, is other nitrogen-containing component in the production of feed for cattle (Li et al., 2019; Yuan et al., 2004);
- preparation of pectin — starch mixtures for feed and other technical purposes (Gu et al., 2013; Yang, 2018);
- production of dietary fiber (Li et al., 2017; Wu, 2016);
- bioconversion into sugar in bioethanol production and extraction of syrup for soaking potato snacks and french fries (Gao, 2012; Ginkel et al., 2005; Wang et al., 2016; Wu, 2016);
- nutrient medium for growing yeast in the production of vitamin B12 (Mayer, 1998);
- nutrient component of the substrate in biogas production (Mayer, 1998; Wang et al., 2016);
- use in the food industry as a prescription ingredient (Bastos et al., 2016; Bengtsson et al., 2011; Cao et al., 2019; Dias et al., 2014).

The possibility and effectiveness of using potato waste as raw ingredient on an industrial scale was proved. It was proposed to use potato pulp as a source of dietary fiber in low-fat sausage technology, thereby strengthening the structure of ready-made low-fat sausages and increasing their yield (Bengtsson, Montelius & Tornberg, 2011). Replacing wheat flour with dried or extruded pulp allows to make pasta for patients with celiac disease (Bastos, Júnior & Caliari de Araujo Pereira, 2016) and in the technology of custard, a similar substitution helps to reduce the amount of digestible starch and glycemic index of the finished product (Cao, Zhang, Guo, Dong & Li, 2019). Partial replacement of wheat flour with potato pulp helps to reduce the lipid content in finished products by 24% in the technology of deep-fried snacks (Dias, Oliveira, Campos & Manoel, 2014), however, such snacks are not balanced in their chemical composition, and the fat content remains quite high.

Snack products are one of the most common among children, young people and middle-aged people, due to their nutritional value and easy consumption, especially in urban conditions. Particular attention is paid to potato snacks due to their taste and low price. However, due to the above disadvantages of this product (high fat content and low content of biologically active substances), their consumption is limited. In order to increase the nutritional value of pulp-based snacks, it is advisable to add raw materials rich in biologically active substances, for example green buckwheat. Chemical composition of green buckwheat and potato pulp is presented in table 1 (Gu et al., 2013; Mazza et al., 2003; Yuan et al., 2004; Zhu et al., 2008).

Table 1. **Chemical composition of green buckwheat and potato pulp**

Indicator	Green buckwheat	Potato pulp
Water, %	9.7—	18.0—31.0
Protein, %	13.0—15.0	3.9—11.4
Fat, %	3.4	3.7
Carbohydrates, %	71.5	53.7
Alimentary fiber, %	5.0—11.0	68.6
Vitamins:		
A, µg	6.0	not found
B1, mg	0.4	-*
B2, mg	0.2	-*
B6, mg	0.4	-*
B9, µg	31.8	160.0
EE, mg	6.7	not found
PP, mg	4.2	-
Minerals, %	1.2	1.6—8.9
Macronutrients:		
Ca, mg	20.7	255—657
Mg, mg	200.0	337—363
Na, mg	3.0	194
K, mg	380.0	8478—8892
Trace elements:		
Fe, mg	6.7	n/a
Zn, mg	2.0	n/a
I, µg	3.3	n/a
Cu, µg	640	n/a
Mn, mg	1.56	n/a
Cr, µg	4.0	n/a
F, µg	23.0	n/a
Mo, µg	34.4	n/a
Si, mg	81.0	n/a
Co, µg	3.1	n/a

Remark: -* — traces of the compound were detected.

The protein content in green buckwheat is in the range of 13.0—15.0%, and its value is due to the presence of up to 18.2% albumin, 43.3% of globulin, 0.8% of prolamin, 22.7% of glutelin and 5.0% of other amino acids. Green buckwheat is a source of amino acids, which have good solubility and high digestibility. As for the pulp, the amount of protein in it reaches in average 6%, which is twice less than in green buckwheat. The value of this protein is provided by the presence of 8 essential amino acids, among which are asparagine — 8.6%, glutamine — 7.1%, alanine — 7.5%, prolamine — 43.6% and valine — 10.5%.

The main fiber components (the amount of fiber is 11%) of green buckwheat are cellulose, non-starch polysaccharides and lignin, for pulp they are pectin, cellulose and hemicellulose, the content of which is 6 times higher than in green buckwheat.

The amount of fat in both raw ingredients is at the same level, while the ash in potato pulp is 7 times higher than in green buckwheat, which explains the higher number of micro- and macronutrients in the pulp. As for vitamins, there is a reverse trend, as their number is much higher in green buckwheat and is represented by vitamins B1, B2, B6, B9, PP, the highest amount takes vitamins EE and A — 6.7 and 6.0 mg, respectively.

Green buckwheat is a source of antioxidants which protect the product from acidification compared to other cereals, which in turn increases the resistance of this ingredient to rancidity during storage and prevents mold in case of high humidity (Hetman, Mykhonik, Kuzmin & Shevchenko, 2021; Wu, 2016).

The complete replacement of wheat flour and dry potato pulp on green buckwheat flour and potato pulp, respectively, will create a ready-to-eat product, balanced in its chemical composition and low in fat. The valuable chemical composition of these raw materials will give healthy properties to products with their content (Шевченко, Сімахіна & Шевченко, 2020).

The purpose of the research was to study the influence of green buckwheat flour on the structural and mechanical properties of dough and on the quality of finished products.

Materials and methods. The influence of dispersion of green buckwheat flour (TM "Skvyryanka" (Ukraine)) on structural and mechanical parameters of dough, sensorial, physicochemical and structural and mechanical indicators of quality of ready-to-eat snacks made on the basis of potato pulp (TM "Vimal" (Ukraine)). In addition, the chemical composition of green buckwheat flour, pulp and ready-made snacks was analyzed.

The green buckwheat was crushed into flour using a laboratory mill ML-2, and then it was sifted on sites of various sizes, which are 8.7; 11; 20; 23; 41/43. As a result, flour with dispersion 200 μm, 310 μm, 390 μm, 670 μm, 850 μm was obtained.

The mixing of the dough was carried out using a mixing machine (Esperanza EKM024 (Poland)), which added not only flour and pulp but egg mélange and salt. The recipe of potato snacks is presented in table. 2. The dough was kneaded with a mass fraction of dry matter of 25.0%. Heat treatment was performed using a household waffle iron (MAGIO MG-397, (China).

Table 2. **Recipe for potato snacks**

Ingredient	Quantity, g
Potato pulp	71.6
Salt:	1.1
Green buckwheat flour	24.5
Egg	2.2
Oil	0.5
Total:	100

In order to establish the influence of different types of starch on the structural and mechanical properties of the dough, general deformation, relatively elastic deformation, softness, reproducibility and plasticity of dough pieces were investigated using a structrometer STS-1 (Moscow) with sphere nozzle.

Heat treatment of dough blanks was performed at a temperature of 140°C for 2—3 min. As a control sample the classic technology of snacks from potato was used (1.5 mm thick potato slices were fried in a deep-fried fryer at a temperature of 150—160°C for 3 minutes).

Sampling for the analysis of the finished product was carried out and sensorial indicators of finished snacks were determined according to methodology, protein content — by Keldal's method, fat — by refractometric method, and carbohydrates — by Schorl's micromethod.

Analysis of the energy value of snacks was determined by the Pokrovsky method per 100 g of finished product. During the calculations, they used the "Norms of physiological needs of the population of Ukraine in basic nutrients and energy" approved by the Ministry of Health of Ukraine for women aged 18—29 years, 1st labor intensity group. The glycemic index of snacks was calculated according to the method developed in the National University of Food Technologies (Patent 40623 UA), which means calculation of the sum of the products of each glycemic index of carbohydrate per 100 g of food product. Statistical processing of the obtained experimental data was performed for three measurements of all studied properties. In the tables there is indicated the number of repetitions and the maximum error in the form of $M \pm m$; n = 3, where M is the error, n is the number of repetitions.

Results and discussion. The degree of dispersion of flour in different ways affects the process of snack production, because it has different chemical composition (Дробот, Шевченко & Літвинчук, 2021). Firstly, its size affects the quality of the dough (kneading process, dough formation and heat treatment) and finished product. That is why it was considered appropriate to analyze the effect of green buckwheat flour of different fractions on the structural and mechanical properties of dough. The results of studies of general deformation, relatively elastic deformation, softness, reproducibility and plasticity of test blanks are presented in table. 3.

Table 3. **Structural and mechanical quality indicators of dough based on pulp and green buckwheat flour**

$M \pm 0.05$; $n = 3$

Indicator	The size of the flour particles of green buckwheat, microns				
	200	310	390	670	850
General deformation, Pa	0.55	0.67	0.70	1.84	1.89
Relatively elastic deformation, Pa	0.48	0.61	0.66	1.18	1.38
Softness, Pa	37.93	48.29	54.04	69.11	80.00
Reproducibility, Pa	48.17	53.33	65.67	68.33	72.83
Plasticity, Pa	22.43	15.73	6.47	6.37	4.71

It was found that the structural and mechanical properties (general deformation, relatively elastic deformation, softness and reproducibility) of the dough from green buckwheat flour with a dispersion of 200 μm to 850 μm increased with increasing dispersion, while the plasticity, on the contrary, decreased. This pattern is explained by the decrease in the number of destroyed and broken grains of starch and protein in flour with bigger size. The more free grains of starch in the dough, the lower its elasticity, the higher the plasticity, because in such systems there are deeper colloidal processes, namely the swelling of starch grains (Drobot & Shevchenko, 2021). Potato pulp has no less significant influence on the structural and mechanical properties of the dough than buckwheat flour, namely because of the presence of approximately 65.0 g/100 g of dietary fiber. These compounds help to increase the stability of the system, and therefore increase the elasticity, softness and reproducibility, due to their high moisture absorption and moisture retention capacity. Potato fiber has capillary structure, that is why water retention occurs not only on the surface of the fiber, but also inside the capillary channels, thereby improving the structure of the finished product (Rubanka, Terletska, Pysarev & Abramova, 2021).

If the dispersion of flour increases from 200 μm to 390 μm, its general deformation and relatively elastic deformation increases by 27% and 37%, respectively. Further increase in dispersion of flour to 850% increases these indicators by 243% and 187%, respectively. Similar results were obtained for such indicators as softness and recoverability, which increased with increasing dispersion of flour, but the increase in the softness of the dough was twice higher than for reproducibility.

As for plasticity, with increasing size of the flour particles from 200 μm to 850 μm, it decreases by 79%.

Therefore, to obtain dough in the production of potato snacks based on potato pulp with the best structural and mechanical properties, it is advisable to use flour with dispersion of 850 microns, which facilitates the formation of kneading process. However, it is necessary to take into account the way in which the size of the flour will affect the strength, and therefore the crunchiness of the finished snacks.

The effect of flour grinding size with particles from 250 to 850 microns on the brittleness of finished snacks was investigated. The results of the influence of the dispersion of green buckwheat flour on the strength of the finished snacks are presented in fig.

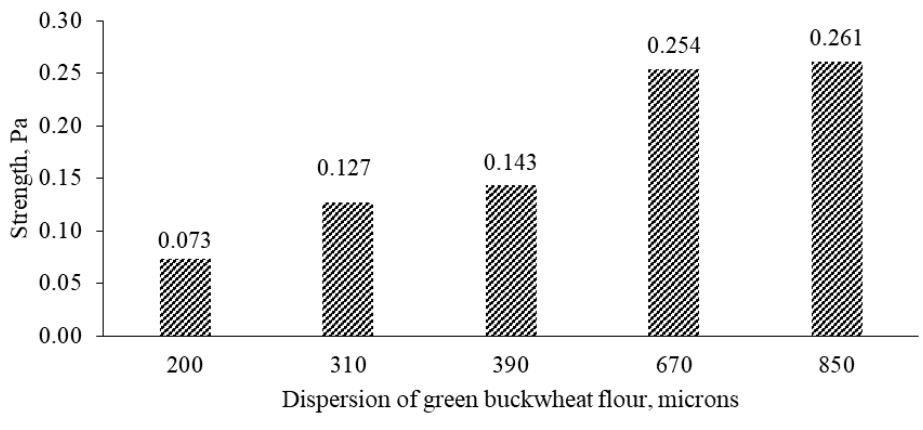

Fig. Influence of dispersion of green buckwheat flour on the strength of ready-made potato snacks, $M \pm 0.05$; $n = 3$

It was established that the strength of finished products increased with increasing size of flour particles, which may be explained by the presence of a smaller amount of free fractions of protein and starch, which gives a paste.

The strength of finished products increased by 73% when doubling the dispersion, namely from 200 microns to 390 microns. Increasing the dispersion of flour by 3.3 times (from 200 microns to 670 microns) increased the strength of snacks by 247%, while 4.3 times increasing (from 200 microns to 850 microns) — only by 257%.

Therefore, taking into account the plasticity, softness, elasticity of the dough and the strength of the finished products, It is recommended to use flour with size of particles — 670 microns, which will allow to get dough with good structural and mechanical properties and ready-made snacks with high strength (crunchiness).

As a result of research, it is proposed the development of potato snacks based on potato pulp and green buckwheat flour with dispersion of 670 microns. However, the quality of finished products remains unclear. Therefore, the sensorial, physicochemical and consumer properties of potato snacks were studied.

The results of studies of sensorial indicators of potato snacks proposed for the development are presented in table. 4.

Table 4. **Sensorial indicators of potato snacks**

Indicator	Characteristics
Appearance	The shape is round, the plates are thin with a pattern on the surface that repeats the look of a waffle iron
Color	Yellow, have a slight darkening at the edges
Taste and smell	Well expressed, peculiar to potatoes, there is a light taste of buckwheat, without extraneous taste and smell

Physicochemical parameters (mass fraction of moisture, ash, mass fraction of chlorides, impurities and the presence of broken slices) are presented in table. 5.

Table 5. **Physicochemical indicators of potato snacks**

Indicator of quality	Control sample	Potato snacks based on potato pulp and green buckwheat flour
Mass fraction of moisture, %	no more than 5.0	4.2
Mass fraction of chlorides, %	no more than 3.0	1.7
Presence of impurities	not allowed	not found
The presence of broken slices, plates (passage through a sieve with a hole size of 20 mm, %)	no more than 10.0	not found

Developed snacks have a pleasant, distinct taste and aroma of potatoes. The products have a round shape, the color is similar to the control sample (light yellow without burnt edges).

According to the results of research of physicochemical parameters, it was determined that the developed snacks have mass fraction of moisture 4.2%, mass fraction of chlorides — 1.7%, the presence of impurities and slices was not found.

Nutritional, energy value and consumer properties are also important characteristics of snacks, which, like sensorial characteristics, influence consumer choice. Therefore, the nutritional, energy value and glycemic index of snacks made from potato pulp and green buckwheat flour were determined.

In the developed snacks based on potato pulp and green buckwheat flour, the content of basic nutrients was determined, according to which the nutritional and energy value and glycemic index was calculated (table 6).

Table 6. **Energy value and glycemic index of potato snacks**

Indicator	Daily requirement, g/100 g	Content, g/100 g	Integral score, %
Proteins	55	14.31	26.01
Fats	56	2.20	3.93
Carbohydrates	320	45.21	14.06
Energy value, kcal	2450	255.24	
Glycemic index, units		15.63	

According to calculations, it was determined that the developed potato snacks cover more than 25% of the daily protein requirement in case of consumption of 100 g of product. But the content of carbohydrates and fat is low, for which the integrated rate is only 14.06% and 3.93%, respectively. The energy value for snacks is 522.5 kcal, which provides the fifth part of the daily energy needs.

No less important consumer characteristic of the developed snacks is their glycemic index. It was found that snacks offered for processing belong to products with low glycemic index, as its value is only 15.63 units and does not exceed the permissible level of 40.0 units for products with low glycemic index. Such results are due to the low glycemic index of the raw materials which were used. Firstly, the pulp is free from a large amount of starch, while fiber, although in large quantities, has a low value of this indicator, only 0.1 units.

Conclusions

Production of potato snacks based on potato pulp and green buckwheat flour solves the global problem of waste-free processing of raw vegetables. The use of buckwheat flour with a dispersion — 670 microns, provides the production of finished snacks with high structural and mechanical properties. The energy value of such snacks is much lower compared to potatoes and is only 255.24 kcal, which is 2 times less than chips fried in oil, because in their production deep fryers aren't used, and therefore the amount of fat is much lower, in addition, the use of pulp, from which starch is washed, also reduces energy value. According to the glycemic index, such snacks belong to the group of products which have a low rate as it does not exceed 40 units and is only 15.63 units. Therefore, they can be consumed by people who control weight and who have diabetes.

References

Дробот, В. І., Шевченко, А. О., Літвинчук, С. І. (2021). Вплив рисового борошна на структурно-механічні властивості тіста та якість хліба. *Наукові праці НУХТ*, 27(5), 114—122. https://doi.org/10.24263/2225-2924-2021-27-5-15.

Шевченко, О. Ю., Сімахіна, Г. О., Шевченко, А. О. (2020). Оздоровче харчування в контексті продовольчої безпеки в Україні. *Наукові праці НУХТ*, 26(6), 36—43.

Bastos, G. M., Soares Júnior, M. S., de Araujo Pereira, M. C. (2016). Physical and sensory quality of gluten-free spaghetti processed from amaranth flour and potato pulp. *LWT — Food Science and Technology*, (65), 128—136. https://doi.org/10.1016/j.lwt.2015.07.067.

Bengtsson, H., Montelius, C., Tornberg, E. (2011). Heat-treated and homogenised potato pulp suspensions as additives in low-fat sausages. *Meat Science,* (88), 75—81. https://doi.org/10.1016/j.meatsci.2010.12.005.

Cao, Y., Zhang, F., Guo, P., Dong, S., Hongjun, Li. (2019). Effect of wheat flour substitution with potato pulp on dough rheology, the quality of steamed bread and in vitro starch digestibility. *LWT — Food Science and Technology*, 111, 527—533. https://doi.org/10.1016/j.lwt.2019.01.034.

Chemical composition and nutritional value. Взято з https://www.ecorod.ua/en/products/entry/view/42.

Cheng, Li., Zhang, X., Hong, Y., Zhaofeng, Li., Caiming, Li., Zhengbiao Gu. (2017). Characterisation of physicochemical and functional properties of soluble dietary fibre from potato pulp obtained by enzyme-assisted extraction. *International Journal of Biological Macromolecules,* 101, 1004—1011. https://doi.org/10.1016/j.ijbiomac.2017.03.156.

Dias, Thays de L.; Oliveira, Tatianne F. de; Campos, Maria R. H. and Soares Junior, Manoel S. (2014). Utilization of residual pulp of potato in snacks as prospect of reducing environmental. *Revista Brasileira de Engenharia Agrícola e Ambiental,* 18(2). https://doi.org/10.1590/S1415-43662014000200014.

Drobot, V., Shevchenko, A. (2021). Influence of pumpkin processing products on structural and mechanical properties of dough and bread quality. *Наукові праці НУХТ*, 27(3), 172—180. https://doi.org/10.24263/2225-2924-2021-27-3-20.

Gao, M.-T., Yano, S., Inoue, H., K. Sakanishi, Gao, M.-T. (2012). Production of ethanol from potato pulp: Investigation of the role of the enzyme from Acremonium cellulolyticus in conversion of potato pulp into ethanol. *Process Biochemistry,* 47(12), 2110—2115. https://doi.org/10.1016/j.procbio.2012.07.031.

Gu, Z., Chen, L., Hong, Y. (2013). Effective utilization technology of potato pulp produced from potato starch industry. *Journal of Food Science and Technology*, 31, (1), 64—69. https://doi.org/10.3969/j.issn.2095-6002.2013.01.014.

Hetman, I., Mykhonik, L., Kuzmin, O., Shevchenko A. (2021). Influence of spontaneous fermentation leavens from cereal flour on the indicators of the technological process of making wheat bread. *Ukrainian Food Journal*, 10(3), 492—506. https://doi.org/10.24263/2304-974X-2021-10-3-6.

Levin, D. B., Zhu, H., Beland, M., Cicek N., Bruce E. Holbein. (2007). Potential for hydrogen and methane production from biomass residues in Canada. *Journal of Bioresource Technology*, 98, 654—660. https://doi.org/10.1016/j.biortech.2006.02.027.

Li, C., Hu, Gu, Z., Yan, H., Zhaofeng, L., Caiming, L. (2019). Characterization of physicochemical properties of cellulose from potato pulp and their effects on enzymatic hydrolysis by cellulose. *International Journal of Biological Macromolecules*, 131, 564—571. https://doi.org/10.1016/j.ijbiomac.2019.02.164.

Mayer, F. (1998). Potato pulp: Properties, physical modification and applications *Polymer Degrad Stab*, 59, 231—235.

Mazza, G., Oomah, B. D. (2003). Buckwheat. *Encyclopedia of Food Sciences and Nutrition*, 692—699. https://doi.org/10.1016/B0-12-227055-X/00132-2.

Rubanka, K., Terletska, V., Pysarev, M., Abramova, A. (2021). Prospects of potato pulp disposal: a review. *Journal of Hygienic Engineering and Design*, 35, 83—95.

Van Ginkel, S. W., Oh, S. E., Logan, B. E. (2005). Biohydrogen gasproduction from food processing and domestic wastewaters. *J Int. J. Hydrogen Energy*, 30, 1536—1542. https://doi.org/10.1016/j.ijhydene.2004.09.017.

Wang, F. Jiang, Y., Guo, W., Niu, K., Zhang, R., Hou, S., Wang, M., Yong Yi, Zhu, C., Jia, C. & Xu Fang (2016). An environmentally friendly and productive process for bioethanol production from potato waste. *Biotechnology for Biofuels*, 9(1), 611—621. https://doi.org/10.1186/s13068-016-0464-7.

Wu, D. (2016). Recycle technology for waste residue in potato starch processing: A review. *Procedia Environmental Sciences,* 3, 108—112. https://doi.org/10.1016/j.proenv.2016.02.015.

Yang, J.-S., Mu, T.-H., Ma, M.-M. (2018). Extraction, structure, and emulsifying properties of pectin from potato pulp. *Food Chemistry*, 244, 197—205. http://dx.doi.org/10.1016/j.foodchem.2017.10.059.

Yuan, H. Zhao, P., Li, Z. (2004). Value and prospect of development and utilization of waste residue in potato starch processing. *J Gansu Science and Technology Review*, 33(6), 67.

Zhu, H. Stadnyk, A., Béland, M., Seto, P. (2008). Co-production of hydrogen and methane from potato waste using a two-stage anaerobic digestion process. *J Bioresource Technology*, 99, 5078—5084. https://doi.org/10.1016/j.biortech.2007.08.083.