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RESEARCH OF CONSUMER PROPERTIES OF BUCKWHEAT PORRIDGE AT THE CUSTOMS EXAMINATION

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The aim of the article is to expand the limits of the application of physico-mathematical methods of evaluating the quality of cereals during their customs examination and to develop the possibilities of exporting buckwheat groats based on the commodity evaluation of its quality. The object of the study is buckwheat groats of different manufacturers.

Keywords: *buckwheat groats, commodity examination, hygroscopic properties, porosity, swelling kinetics*

ДОСЛІДЖЕННЯ СПОЖИВЧИХ ВЛАСТИВОСТЕЙ КАШ ГРЕЧАНИХ ПІД ЧАС МИТНОЇ ЕКСПЕРТИЗИ

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Об'єктом дослідження є гречана крупа першого ґатунку різних виробників: ТМ «Розумний вибір», ТМ «Хуторок», ТМ «Сквирянка», ТМ «Своя лінія», ТМ «Терра». Метою роботи є розширення меж застосування фізико-математичних методів оцінки якості круп під час їх митної експертизи та розвиток можливостей експорту крупи гречаної на основі товарознавчої оцінки її якості.

Дослідженнями гігроскопічних властивостей крупи гречаної встановлені значення відносної вологості повітря, за яких можливе тривале зберігання даної продукції у паропроникному упакуванні, %: ТМ «Розумний вибір» – 69; ТМ «Хуторок» – 68; ТМ «Сквирянка» – 69; ТМ «Своя лінія» – 63; ТМ «Терра» – 72. У разі необхідності зберігання крупи гречаної за більшої відносної вологості повітря зберігання необхідно проводити у паронепроникному упакуванні. Дослідженнями пористості круп установлені

значення відношення середнього радіусу пор до найбільш імовірного, $\cdot 10^{-3}$: ТМ «Розумний вибір» – 2.53, ТМ «Хуторок» – 2.15, ТМ «Сквирянка» – 2.77, ТМ «Своя лінія» – 1.98, ТМ «Терра» – 1.71. Результат пояснює характер поведінки ізотерм сорбції, оскільки, чим більше відношення середнього радіусу пор до найбільш імовірного, тим більше вологи може поглинути зразок. Дослідженнями процесу набухання зразків круп встановлено кінцевий вологовміст зразків після обводнення їх у питній воді за температури 20…25°С складає, кг сух. реч./кг води: ТМ «Розумний вибір» – 1.83, ТМ «Хуторок» – 1.80, ТМ «Сквирянка» – 1.90, ТМ «Своя лінія» – 1.73, ТМ «Терра» – 1.68. Установлено, що зразки досягають значень вологовмісту, близького до максимального, за різної тривалості обводнення, хв.: ТМ «Розумний вибір» та ТМ «Хуторок» – 60…70; ТМ «Сквирянка» – 50…60; ТМ «Своя лінія» та ТМ «Терра» – 70…80.

Відзначено, що отримані результати є об'єктивними показниками якості крупи гречаної, які можуть бути використані під час митних експертиз цієї продукції в країнах Європейського Союзу.

Keywords: *крупа гречана, товарознавча експертиза, гігроскопічні властивості, пористість, кінетика набухання*

Problem statement in general terms. Cereals are a strategic product, which in Ukraine is traditionally included in the set of essential foods [1].

Since the 7th century AD, buckwheat has become one of the most popular grain crops in the areas of Slavic settlement, and dishes prepared from it have become national [2]. Buckwheat, as one of the most popular cereals on the domestic market, always remained a priority. It is known that this plant is unpretentious and can produce a harvest on poor lands, where no other grain crop will grow. The agrotechnical importance of buckwheat is that due to its unpretentiousness, as well as its impressive ability to independently displace weeds from its land, it reduces weediness in fields [3]. It is a good predecessor, as it assimilates hard-to-reach compounds of phosphorus and potassium for its own nutrition and leaves them in the soil with plant remains [4]. Buckwheat is an insurance crop for replanting dead winter crops, it is grown in post-mowing and post-harvest crops, as well as for green fodder and green fertilizer [5].

Analysis of recent research and publications. To date, the state of war in Ukraine has caused a decrease in the cultivation and production of cereals, as the population in the country has decreased, and purchasing power is falling. In 2022, grocery exports recovered by only 20-30% of normal export volumes. However, in 2024, according to the forecast of the Ministry of Agrarian Policy, a record buckwheat harvest is planned [6].

During the war, the main export destination for Ukrainian grains is the European Union (EU) market. Among the promising products for the EU is the export of buckwheat products from Ukraine. Buckwheat export across the

border with the EU is an opportunity that will help the Ukrainian economy and domestic farmers today, and perhaps help to recover in the future [7].

At the same time, it should be noted that, according to the company "UkrAgroConsult", the level of shadow production of cereals in Ukraine is about 30% [8]. Among them, the Ukrainian market has a large number of products that are ordered in Poland, for example, or in Turkey and packaged under the "label" of domestic manufacturers. Therefore, it is important for farmers to grow cereal crops, namely, buckwheat products in a quantity that will fully supply the Ukrainian market, and a portion of which will remain for export. However, today, in order to restore the export of products, it is necessary to simplify logistics, additional transshipment points on the railways in the border areas, and to simplify the regime for the passage of road transport.

It should also be noted that in 2022 there was a ban on the export of buckwheat and salt suitable for human consumption. However, in 2023, according to the Resolution of the Cabinet of Ministers of Ukraine, the ban on the export of buckwheat was canceled, but zero quotas were introduced for some groups of goods [9].

The export of food products from the territory of Ukraine is accompanied by the registration and submission to customs of documents necessary for customs control, which confirm the country of origin of the goods, the quality and safety of the goods, accrued customs payments, etc.

Customs examinations include a number of examinations, which include: material science, identification, chemical, technological, commodity science, ecological, art science, certification, value, evaluation, gemological, technical forensic and other types. For such products as buckwheat groats, it is necessary to select a commodity value examination, which is carried out in order to determine the value of the product on the basis of its quality indicators and main properties.

Organoleptic and physico-chemical indicators (hygroscopic properties, porosity, reproducibility) are the main characteristics that fairly objectively give an assessment of the quality of food products of plant origin, namely buckwheat groats. However, information about these physico-chemical indicators, as well as their compliance with the regulatory documentation in force in Ukraine, as a rule, is not provided. At the same time, it should be noted the relevance of expanding the limits of the application of physico-mathematical methods of product quality assessment during its customs examination, which are widely used in the EU countries [10].

The aim of the article is to expand the limits of the application of physico-mathematical methods of evaluating the quality of cereals during

their customs examination and to develop the possibilities of exporting buckwheat groats based on the commodity evaluation of its quality.

Description of the main research material. The ability of food products to not change their properties for a long time is largely determined by their hygroscopic properties, that is, the ability to release or absorb water vapor from the environment. Being in an atmosphere of moist air, the food product can exchange mass with the external environment. If the partial pressure of the water vapor near the surface of the product is greater than the partial pressure of the vapor in the air, then evaporation (desorption) occurs, and the mass and moisture content of the product decrease, if the ratio of partial pressures is reversed, then the product is moistened (sorption) - the mass and moisture content of the product increase. At the same time, the product is characterized by an equilibrium moisture content - the pressure of water vapor above the surface and in the atmosphere is equalized. These processes play an important role during the storage of food products and they determine the conditions and terms of storage.

The object of the study is buckwheat groats of the first grade of different manufacturers: TM "Rozumnyi vybir", TM "Khutorok", TM "Skvyrianka", TM "Svoya linia", TM "Terra".

The tensometric method was used to study the sorption and determination of the equilibrium moisture content of buckwheat groats from different manufacturers. The studied sample was placed in desiccators with a fixed value of relative air humidity φ. All desiccators were kept at a constant ambient temperature during the measurements (25°C). The duration of the product's stay in the desiccator was determined by the sample reaching a constant mass.

The sorption isotherms of the studied samples are shown in Fig. 1.

The isotherms for samples 1–4 have the same character. Three characteristic areas can be distinguished on them, which correspond to monomolecular and polymolecular sorption of moisture and the area corresponding to the swelling of the samples. As for sample 5, the section corresponding to monomolecular sorption is missing on the sorption isotherm. A change in the type of moisture connection with the dry substances of the studied samples is evidenced by a change in the angle of inclination of the section of the sorption isotherm to the axis on which the relative humidity of the air in the desiccator is deposited.

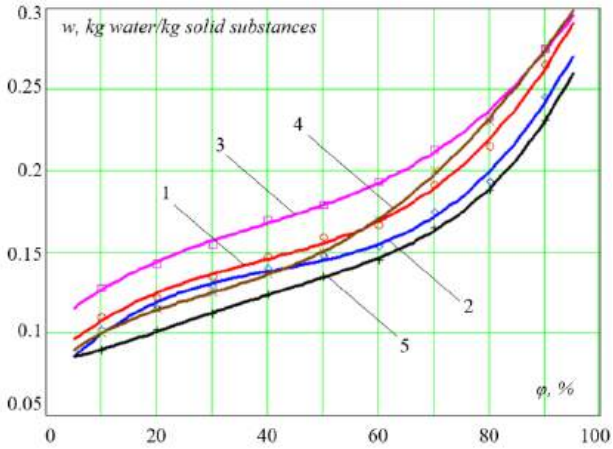

Fig. 1. Sorption isotherms of buckwheat groats from different manufacturers: 1 – TM "Rozumnyi vybir"; 2 – TM "Khutorok"; 3 – TM "Skvyrianka"; 4 – TM "Svoya linia"; 5 – TM "Terra",
built by the authors

The separation of sorption isotherms into sections was carried out as follows. Arrays of experimental data were divided into parts according to the number of sections into which the corresponding sorption isotherm was divided: for samples 1–4, the number of such parts was equal to three, for sample 5 – two. Next, a linear approximation of the experimental data included in the corresponding part of the array was performed. At the same time, points from adjacent parts of the general array of experimental data were alternately added. The number of points from adjacent parts of the array was chosen based on the value of the correlation coefficient between the approximation function and the experimental data of the part of the array filled in this way. Points were added until the correlation coefficient reached a value of less than 0.95.

The given results show that in the range of relative humidity from 10 to 19%, samples 1–4 are in the region of monomolecular sorption. With a further increase in the relative humidity of the air, buckwheat groats samples 1–4 move into the region of polymolecular sorption. As noted above, sample 5 does not have a pronounced region corresponding to monomolecular sorption. At the same time, the samples have different ranges of relative humidity, which correspond to the area of their polymolecular sorption. Thus, sample 5 is in the region of polymolecular sorption at relative humidity from 10 to 72%, and samples 1–3 at relative humidity from 18...19 to 68...69%.

Buckwheat sample 5 has the smallest upper limit of the region of polymolecular sorption. The corresponding range of relative humidity for this sample is from 16 to 63%.

When air humidity increases relative to the upper limit of the range corresponding to polymolecular sorption, moisture is absorbed by microcapillaries and the samples swell. Since the character of the isotherms for the studied samples of buckwheat groats does not have pronounced asymptotes parallel to the axis of the moisture content, further moistening of such samples is possible upon direct contact with the liquid. The obtained result indicates the possibility of their long-term storage in polymer packaging at a relative humidity that corresponds to the upper limit of the range of polymolecular sorption.

For samples of buckwheat groats from different manufacturers, these values of relative humidity are respectively equal to: TM "Rozumnyi vybir" – 69%; TM "Khutorok" – 68%; TM "Skvyrianka" – 69%; TM "Svoya linia" – 63%; TM "Terra" – 72%.

The studied products can be stored in vapor-permeable packaging at a relative humidity of no more than the given values at a temperature of no more than 25°C. If there is a need to store buckwheat groats at a relative humidity higher than the values given for each of the manufacturers, then the storage must be carried out in vapor-tight packaging.

It should be noted that the sorption isotherms of the studied buckwheat samples are located at different heights relative to the axis on which the moisture content is deposited. The result obtained is explained by the different porosity of buckwheat groats from different manufacturers, which is examined below.

Obviously, the ability of food raw materials and products to absorb or release moisture is determined by their porosity. An objective characteristic of porosity is the distribution of pores of the studied samples by radii.

Determination of the differential function of the distribution of pores by radii in buckwheat groats from different manufacturers was carried out using the sorption isotherms of the studied raw materials as follows [11, 12]. Sorption isotherms for buckwheat groats from different manufacturers were obtained using the strainometric method. Next, the experimental data were approximated by a function of the form [11, 12]:

$$\varphi = \frac{w^{A_3}}{A_1 + A_2 w^{A_3}}, \quad (1)$$

where A_1, A_2, A_3 – approximation coefficients; w – moisture content.

The use of this approximation function makes it possible to obtain such an important structural and physical characteristic as the differential function of the distribution of pores by radii $f_n(R^*)$.

The differential function of the distribution of pores by radii is determined as follows:

$$f_n(R^*) = \frac{1}{\sqrt{2\pi}\sigma_R R^*} exp\left(-\frac{(ln(R^*)-m_R)^2}{2\sigma_R^2}\right), \quad (2)$$

where m_R and σ_R – parameters of the log-normal distribution;

R^* – dimensionless pore radius $R^* = (R - d_0)/d_0$; R – pore radius, m; d_0 =0.3·10^{-9} m – water molecule radius.

The parameters of the log-normal distribution are calculated [11, 12] according to the formulas:

$$m_R = \left(\frac{A_2}{0{,}433}\right)^{1{,}247}, \quad (3)$$

$$\sigma_R = -\frac{ln(6{,}12A_1)}{0{,}625}\left(\frac{A_3-0{,}957}{0{,}223}\right)^{-0{,}6}. \quad (4)$$

The average was determined according to the defined analytical type of pore distribution functions by radii:

$$\bar{R} = d_0[1 + exp(m_R + {\sigma_R}^2/2)] \quad (5)$$

and the most probable pore radius (center of distribution):

$$R_m = d_0[1 + exp(m_R - {\sigma_R}^2)]. \quad (6)$$

Pore distribution functions by radii for buckwheat groats from different manufacturers, calculated from the sorption isotherms of this raw material using formulas (1)–(4), are presented in Fig. 2.

The differential functions of the distribution of pores by the radii of buckwheat groats from different manufacturers shown in Fig. 2 are normalized to the maximum value for clarity.

The average and most likely pore radius calculated by formulas (5) and (6) are given in Table 1.

The obtained distribution functions have a similar nature and close positions of the maxima relative to the axis on which the dimensionless radius of the pores is laid, which is confirmed by the most probable radii also given in the table: the spread of their values is within the margin of error.

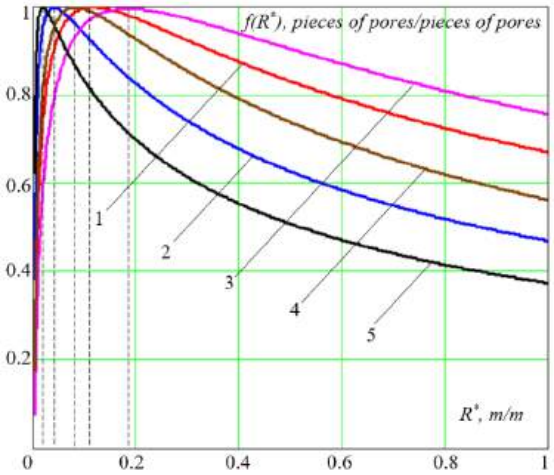

Fig. 2. Differential functions of the distribution of pores by the radii of buckwheat groats from different manufacturers: 1 – TM "Rozumnyi vybir"; 2 – TM "Khutorok"; 3 – TM "Skvyrianka"; 4 – TM "Svoya linia"; 5 – TM "Terra", *built by the authors*

As for the width of the line, the largest width in the function of the distribution of pores by radii is for buckwheat groats from TM "Skvyrianka", and the smallest – from TM "Terra". As a result, buckwheat groats from TM "Skvyrianka" have the largest average radius, and TM "Terra" has the smallest. Buckwheat groats from other producers occupy an intermediate position.

Table 1 – **Average and most likely pore radius of buckwheat groats from different manufacturers**

Manufacturer	$\bar{R}\cdot 10^{7}$, m	$R_m\cdot 10^{10}$, m
TM "Rozumnyi vybir"	4.128	10.443
TM "Khutorok";	2.331	5.012
TM "Skvyrianka"	6.291	17.426
TM "Svoya linia"	1.469	2.908
TM "Terra"	1.017	1.739

Source: compiled by the authors

The greater the ratio of the average pore radius to the maximum possible radius of the material, the more moisture it can absorb. The values of these ratios for the studied raw materials, 10^{-3}: TM "Rozumnyi vybir" – 2.53, TM "Khutorok" – 2.15, TM "Skvyrianka" – 2.77, TM "Svoya Linia" –

1.98, TM "Terra" – 1.71. Such values of the ratio of the average pore radius to the most probable one explain the behavior of the sorption isotherms presented in Fig. 1. The sorption isotherm for buckwheat groats from TM "Skvyrianka", which has the largest value of the ratio of the average pore radius to the most probable one, is higher than other samples, and the isotherm for buckwheat groats from TM "Terra" is the lowest, since this ratio is the smallest for this sample.

The consequence of such redistribution is the different property of buckwheat groats from different producers to absorb moisture not only from the surrounding gas environment during storage, but also the property to swell in the wetting liquid before and during cooking.

The swelling kinetics of the studied samples was obtained by watering them for a certain time according to the method used to determine physico-chemical parameters in food technologies. A sample of the determined mass (30...40 g) is placed in a container made of perforated material. Immerse the container with the material in a vessel with water. After a specified time interval (1...5 min.), the container with the sample is taken out of the water and the increase in mass of the sample under study is recorded. These operations are repeated until the mass of the sample changes. The first four measurements are carried out every 5 minutes, the next four measurements – every 10 minutes, further measurements – every 20 minutes. Next, the ratio of the mass of absorbed water to the mass of dry substances of the sample is calculated for each point of measurement and the change in the calculated moisture content is plotted with the change in the duration of its watering.

The obtained swelling kinetics for the studied buckwheat groats from different manufacturers at a temperature of the wetting liquid (drinking water) of 20...25°C are shown in Fig. 3.

The swelling kinetics of the examined buckwheat groats samples from different producers have a similar character. The value of moisture content increases monotonically. As the duration of watering of the sample increases, its moisture content tends asymptotically to the final one.

The differences in the swelling kinetics of the investigated buckwheat groats' samples from different manufacturers are as follows. First, the studied samples have different final moisture content. Thus, sample 3 has the highest final moisture content, its value is 1.90 kg dry matter /kg of water. Next are samples 1, 2, 4, which, respectively, have the final moisture content, dry kg. substance/kg of water: 1.83; 1.80; 1.73. Sample 5 has the smallest final moisture content, its value is 1.68 kg dry matter /kg of water.

Secondly, the samples reach values of moisture content close to the maximum for different durations of watering. Thus, sample 3 reaches a value of moisture content close to the maximum (differs from the maximum by no

more than 10%) for a duration of watering of 50...60 minutes. Samples 1, 2 reach the value of moisture content, which differs from the maximum by no more than 10%, for the duration of irrigation – 60...70 min., and samples 4, 5 – 70...80 min.

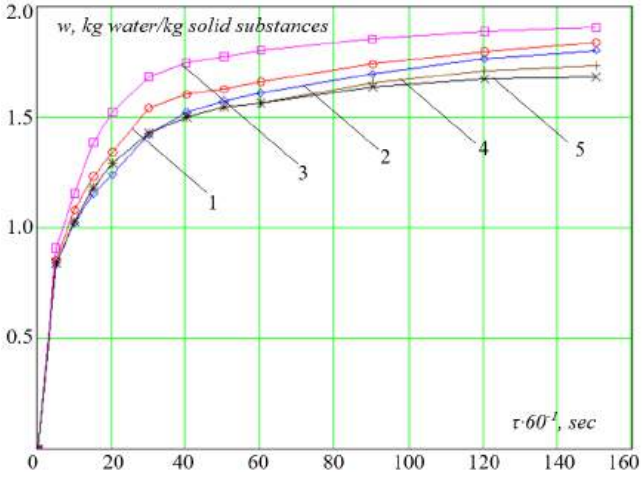

Fig. 3. Swelling kinetics of buckwheat groats from different manufacturers: 1 – TM "Rozumnyi vybir"; 2 – TM "Khutorok"; 3 – TM "Skvyrianka"; 4 – TM "Svoya linia"; 5 – TM "Terra", *built by the authors*

The obtained differences are due to the different porosity of buckwheat groats' samples from different manufacturers, which correlates with the results obtained during the study of the differential functions of the distribution of pores by radii for the studied samples. Sample 3 has the most developed porosity and, as a result, it reaches a moisture content close to the final one in a larger quantity and in a shorter period of time. Sample 5 has the least developed porosity, which entails a decrease in the maximum amount of moisture that the sample can absorb, as well as an increase in the duration of its swelling. Other samples occupy an intermediate position between samples 3 and 5. It should be noted that a higher final moisture content and a shorter duration of its achievement are more acceptable functional and technological properties of cereals, including buckwheat.

The obtained results should obviously be considered objective indicators of the quality of buckwheat groats, as they are determined by physical and mathematical methods used in scientific research in the food industry. These results obtained by fundamental methods are more acceptable

compared to the results obtained by express methods, which are most often used during customs examinations.

Based on their objectivity, the obtained indicators of the quality of the studied buckwheat groats can be used during the customs examination of this product in the EU countries, namely, during its commodity examination. This makes it possible to expand the possibilities of exporting buckwheat groats to EU countries, which is important for the activities of Ukraine in the conditions of martial law.

A limitation of the conducted research is an incomplete commodity examination of the investigated buckwheat groats. Another limitation is that the study was conducted only on buckwheat groats. The expansion of the range of researched products is a prospect for further research.

Conclusions. Studies of the hygroscopic properties of buckwheat groats from different manufacturers have determined the values of relative air humidity at which long-term storage of this product in vapor-permeable packaging is possible. These relative humidity values are respectively equal to: TM "Rozumnyi vybir" – 69%; TM "Khutorok" – 68%; TM "Skvyrianka" – 69%; TM "Svoya linia" – 63%; TM "Terra" – 72%. If it is necessary to store buckwheat groats at a relative humidity higher than the values given for each of the manufacturers, storage must be carried out in vapor-tight packaging.

It has been established that the sorption isotherms of the studied buckwheat groats' samples are at different heights relative to the axis on which the moisture content is deposited. The obtained result is explained by the different porosity of buckwheat groats from different manufacturers.

By researching the porosity of buckwheat groats from different manufacturers, the values of the ratio of the average pore radius to the most probable were established, $\cdot 10^{-3}$: TM "Rozumnyi vybir" – 2.53, TM "Khutorok" – 2.15, TM "Skvyrianka" – 2.77, TM "Svoya linia" – 1.98, TM "Terra" – 1.71. These values explain the behavior of the sorption isotherms, since the greater the ratio of the average pore radius to the most probable, the more moisture the sample can absorb. It is noted that the consequence of such redistribution is the different ability of buckwheat groats from different manufacturers to absorb moisture not only from the surrounding gas environment during storage, but also the ability to swell in the wetting liquid before and during cooking.

Studies of the swelling process of buckwheat groats from different manufacturers have established that the studied samples have different final moisture content. The final moisture content of the samples after watering them in drinking water at a temperature of 20...25°C is kg dry matter/kg of water: TM "Rozumnyi vybir" – 1.83, TM "Khutorok" – 1.80, TM "Skvyri-

anka" – 1.90, TM "Svoya linia" – 1.73, TM "Terra" – 1.68. It has been established that the samples reach values of moisture content close to the maximum (differs from the maximum by no more than 10%) for different durations of watering, min.: TM "Rozumnyi vybir" and TM "Khutorok" – 60...70 min.; TM "Skvyrianka" – 50...60 minutes; TM "Svoya linia" and TM "Terra" – 70...80 minutes.

It is noted that the obtained differences are due to the different porosity of buckwheat groats' samples from different manufacturers, which correlates with the results obtained during the study of the differential functions of the distribution of pores by radii for the specified samples. It is noted that a higher final moisture content and a shorter duration of its achievement are more acceptable functional and technological properties of cereals, including buckwheat.

It is noted that the obtained results are objective indicators of the quality of buckwheat groats, which can be used during customs examinations of these products in the EU countries.

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