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Suitability of potato tubers of different varieties for processing

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Abstract. Drying is one of the most common ways to process potato tubers. To produce high-quality dried products, the quality of raw materials is crucial, and it depends on the varietal characteristics. The purpose of this study was to investigate the suitability of potato tubers of five varieties for convective drying without blanching. The study employed the experimental method according to the developed research scheme, the laboratory method was used to determine the organoleptic, morphological, and

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biochemical quality indicators of fresh tubers and dry products, and the statistical method was used to process the research results mathematically. It was found that tubers of the Povin variety contained the greatest amount of dry matter and starch (24.6% and 18.4%, respectively), while vitamin C was found in Sante and Povin (over 11 mg%). The lowest amount of sugars was accumulated in the tubers of the Koroleva Anna variety – 0.32%. It was found that with an increase in the dry matter content of tubers, the starch content increases substantially (r = 0.98), and the sugar content significantly affects the degree of darkening of dry products (r = 0.74). The nitrate content of tubers of all varieties did not exceed the maximum permissible concentration. It was found that when potato tubers are used for convective drying, 17.1-24.5% of dry products can be obtained and 4.1-5.8 kg of prepared raw materials can be consumed. The dry matter content of the tubers and the amount of waste substantially affect the yield of the finished product. The most suitable for convective drying without blanching are the Koroleva Anna tubers, which provide a 24.5% yield of finished products with a tasting score of 5 on a 5-point scale. When using other varieties of tubers for convection drying, blanching or other methods should first be used to stabilise the colour. The materials of this study are of practical value for vegetable growers, breeders, and specialists of processing enterprises when choosing a potato variety for drying

Keywords: varietal characteristics; quality; tasting; darkening; drying; dry products

Introduction

Potato tubers, due to their high content of valuable compounds for consumers, their cost-effectiveness, and versatility, are of great global importance for food security. Ukraine is one of the world's five largest potato producers, growing 20-22 million tonnes of tubers annually. The breakdown of the tubers harvested is as follows: consumption by households is 33% (6.1 million tonnes); use for feed purposes is 20% (3.8 million tonnes); seeds are 27% (5 million tonnes); and processing is 1.0%. The number of fast-food outlets has grown considerably in Ukraine. In addition, due to Russia's aggression and frequent power cuts, demand for convenience foods, including dry mashed potatoes, has increased. Most potato products (over 90%) are imported. Only the creation of high-quality domestic products will help to displace imported products. Furthermore, the production of potato products will provide value-added products, filling the budgets of local communities and the country as a whole, which is important in the post-war reconstruction. Selecting potato varieties suitable for a particular processing method will not only guarantee quality products, but also reduce production costs (Davydenko *et al.*, 2020). According to H. Campos & O. Ortiz (2020), the versatility of potato tubers is determined by the content of a significant number of biochemical parameters. They accumulate about 26% of dry matter, of which 80-85% is starch and almost 3% is protein. Tuber carbohydrates are a valuable source of energy for the human body, while the protein is equivalent in quality to that of milk, eggs, and beef, and is superior to that of cereals, soybeans, and beans. M.M. Islam *et al.* (2022) note that the dry matter, starch, and reduced sugars content of tubers are crucial for the production of quality potato products.

Drying tubers is a relevant area of their processing. According to S. Chikpah *et al.* (2022), this is the way to preserve the biological valuable elements contained in fresh raw materials. Since the drying process removes free and some bound moisture, dry products are a stabilised concentrate of nutrients that can be easily transported and stored for a long time. In addition, the dry products do not contain any artificial or chemical preservatives, dyes, flavours, and after a short soak, they restore their properties. Dried tubers are used to produce dry mashed potatoes, chips, flakes, as additives for bakery products, etc.

There are many common points in the production technology of dried products. Specifically, both our long-term research and the studies of scientists from other countries have confirmed that their quality will significantly depend on the quality of raw materials, which is primarily determined by varietal characteristics, the content and ratio of macro- and microelements, drying methods, etc. O. Zavadska *et al*. (2020) found that one of the most common, cost-effective methods of drying vegetables, including potato tubers, is the convective method, which uses heated air. The quality and yield of dry products in convection drying depends primarily on the air temperature and the thickness of the cut pieces.

The most common defects in raw and processed tubers include darkening of the flesh. It is the appearance of food that affects commercial competitiveness and decisions about the suitability of its consumption. Furthermore, darkening of tubers can lead to a decrease in their nutritional and biological value. Scientists from different countries are investigating the causes of tuber flesh darkening and suggesting solutions to prevent it. Thus, S. Gunko *et al*. (2023) found a direct correlation between potassium content and the degree of darkening of potato tubers, namely, with an increase in potassium content in tubers, their resistance to darkening during heat treatment increases. Furthermore, the researchers argue that the ability to accumulate minerals in tubers is considerably influenced by varietal characteristics.

E. Wszelaczyńska *et al*. (2023) note that the tendency to darkening of tubers increases significantly due to stress factors arising during their cultivation and storage. Long-term storage leads to a 22% increase in total sugars and a 49% increase in reducing sugars. As noted by R. Hussain *et al*. (2022), it is the increase in the content of inverted sugars, including glucose, in tubers during their heat treatment (drying) that causes darkening of their flesh due to the appearance of dark-coloured melanoidins as a result of the reaction of sugars with amino acids. The conversion of starch to glucose also occurs during storage at low temperatures. A. Amjad *et al*. (2019) believe that the deterioration of tuber quality and an increase in the tendency to darkening is caused by non-compliance with the recommended temperature and humidity conditions during storage. The colour change of raw and cooked potatoes is also substantially affected by the temperature and duration of heat treatment (Syabana *et al.*, 2022).

To prevent colour changes or to obtain tubers that are more resistant to darkening, researchers suggest using biostimulants and hydrogels, which will reduce the effects of stress factors during plant cultivation. G. Bobo-García *et al*. (2020) note that the main enzyme regulating the tuber darkening is polyphenol oxidase. To reduce its activity, the researchers suggest using a variety of substances: chelating agents, inhibitors, natural extracts, and physical treatment.

Thus, darkening of the flesh of potato tubers is one of the key problems affecting the quality, nutritional value, and profitability of potato products. Therefore, the search for ways to solve this problem is relevant. Before drying, blanching of tubers is often used to prevent darkening of the finished product, but it leads to partial leaching and loss of nutrients and additional energy consumption, which increases production costs.

The purpose of this study was to investigate the suitability of potato tubers of different varieties for drying without additional processing. To fulfil the stated purpose, the tasks were identified as follows:

- to assess the quality of freshly harvested tubers and predict their suitability for processing;
- to determine the amount of waste in preparing tubers for drying and the yield of dried products;
- to assess the quality of dried products and the resistance of tubers to darkening without blanching before drying.

Materials and Methods

The study was conducted in 2022-2023. To fulfil the purpose and complete the objectives of the study, five potato varieties that are common in production were selected, namely: Svitanok

Kyivskyi, Koroleva Anna, Povin, Sante, and Tsyhanka. The Ukrainian variety Svitanok Kyivskyi, listed in the Register of Plant Varieties and recommended for the Polissia zone (State register of plant varieties…, 2020), was used as a control.

The economic, biological, and organoleptic analyses of potato tubers were performed in the scientific and educational laboratory of the Prof. B.V. Lesyk Department of Technology of Storage, Processing, and Standardisation of Crop Production of the National University of Life and Environmental Sciences of Ukraine according to generally accepted methods (Skaletska & Podpryatov, 2014). Freshly harvested tubers were evaluated for the content of the main biochemical parameters. Specifically, the dry matter content was determined by drying to a constant weight in an oven, starch – by specific weight, total sugars – by the cyanamide method, and vitamin C – by using a 2,6 dichlorophenolindophenol solution. A nitrate tester was used to determine the nitrate content.

To evaluate the suitability of potato tubers for drying, average samples of each variety weighing 4 kg were selected. Preparation of tubers for processing included weighing them, thoroughly washing, cleaning, and re-weighing (the difference was used to determine the amount of waste). The prepared tubers were cut into identical slices no more than 0.5 cm thick, evenly placed on the trays of a convective dryer DEXDFD-510P (TM DEX, DEXkee Elec-Technology Co. LTD, China) and loaded into the dryer chamber preheated to 60 °C (Fig.1). The raw materials were dried until they were ready, which was determined organoleptically.

Figure 1. *General view of tubers prepared for drying and the convection dryer DEXDFD-510P*
Source: photographs taken by the authors of this study

The dry products were evaluated for a set of organoleptic and technological indicators, and their resistance to darkening was determined. The organoleptic evaluation of dry potatoes and the degree of their darkening were assessed on a 5-point scale according to the following gradation: 5 points – pieces are light, clean, white, or straw yellow, fully matching the colour of the raw material; 4 – up to 20% of the surface is slightly darkened; 3 – up to 40% of the surface is darkened; 2 – up to 60% of the surface is significantly darkened; 1 – pieces are darkened on the surface by more than 60%.

Determination of swelling dynamics and swelling coefficient of dried products. A 5 g sample was taken from the middle sample, 50 g of distilled water was added, and the sample was kept for one hour (60 min). After 20 min and 40 min of swelling, intermediate weighing was performed. The swelling coefficient was calculated as the ratio of the product weight after 60 minutes to the initial weight of the sample. The results were processed mathematically, and the least significant difference (LSD), correlations, and confidence intervals were calculated using generally accepted methods. The study was conducted following

the Convention on the Trade in Endangered Species of Wild Fauna and Flora (1973) and the Convention on Biological Diversity (1992).

Results and Discussion

The formation of the chemical composition of potato tubers is a complex and lengthy process. It depends on a set of factors, the coincidence of which allows obtaining valuable or, conversely, unsuitable raw materials for processing. The yield and quality of dry products are substantially affected by the dry matter content of raw materials – high dry matter content ensures the profitability of processing and improves the quality of the finished product (Furrer *et al.*, 2018). According to A. Mazur (2013), an increase in the dry matter content of tubers by only 1% increases the yield of dried products by 1 kg per 100 kg of raw material, and the profitability of processing by 10-20%. French fries, crisps, or dried products made from tubers that contain little dry matter will be soft and watery (Amjad *et al.*, 2019). However, too high a content of dry matter will cause dryness, density, and brittleness of the finished products (Zavadska *et al.*, 2021). The most suitable tubers for drying are those containing at least 21% dry matter, including 14-16% starch and no more than 0.4% monosugars.

According to the results of the study, during the growing season, 19.5-24.6% of dry matter was accumulated in the tubers of the potato varieties under study (Table 1). The difference between the variants in this indicator reached 5.1%. It can be concluded that the dry matter content of tubers of all varieties, except for Tsyhanka, was suitable for drying. The highest dry matter content was found in tubers of the Povin variety – 24.6%, which is 2.2% greater than in the control.

Table 1. *The content of the main biochemical parameters in potato tubers of different varieties, average for 2022-2023*

Variety	Content in tubers				
	dry matter, %	starch, %	sugars (total), %	vitamin C, mg %	nitrates, mg/kg**
Svitanok Kyivskyi (control)	22.4 ± 0.8*	16.7 ± 0.4	0.36 ± 0.04	8.9 ± 2.2	138 ± 24
Koroleva Anna	23.1 ± 0.5	17.6 ± 0.2*	0.32 ± 0.03	8.5 ± 1.4	116 ± 18
Povin	24.6 ± 0.7	18.4 ± 0.3*	0.57 ± 0.04	9.6 ± 2.1	138 ± 16
Sante	21.9 ± 0.6	15.2 ± 0.3*	0.40 ± 0.03	11.4 ± 1.6	131 ± 26
Tsyhanka	19.5 ± 0.4*	13.7 ± 0.2*	0.62 ± 0.02	11.0 ± 1.8	107 ± 12

Note: * – values of biochemical parameters are mean values ± standard deviation (n = 3); ** – maximum permissible concentration (MPC) – 250 mg/kg
Source: developed by the authors of this study

K. Beals (2019) found that the basis of the dry matter of potato tubers is starch. Its share of the total dry matter content ranges within 70-80%. This pattern was confirmed in the present study. The starch content in tubers of the varieties under study ranged within 13.7-18.4%, which was 70-76% of the dry matter weight. The highest content of this element, as well as dry matter, was found in tubers of the Povin variety – 18.4%, which is 1.7% greater than in the control. The correlation analysis revealed a strong direct correlation between dry matter and starch content – r = 0.98, which confirms the data of A. Furrer *et al.* (2018) and previous findings of the authors of the present study.

According to E. Wszelaczyńska *et al.* (2023), the amount of sugars in tubers significantly depends on the varietal characteristics, their physiological state, growing conditions, and storage time. A. Amjad *et al.* (2019) found that freshly harvested tubers are typically characterised by a low sugar

content, averaging 0.5-0.6% per raw weight. The present study confirmed the dependence of sugar accumulation on varietal characteristics. Under the same growing conditions, the difference between the variants under study was substantial. Thus, in the tubers of the Koroleva Anna variety, they contained 0.32%, while in the Tsyhanka variety almost twice as much – 0.62% (0.26% more than in the control). According to this indicator, tubers of the Tsyhanka variety were unsuitable for drying without preliminary blanching and were predictably more prone to darkening compared to other variants under study.

O. Külen *et al.* (2020) proved that potato tubers also contain biologically valuable substances and vitamins, namely riboflavin, thiamine, pyridoxine, pantothenic and nicotinic acids, carotenoids, etc. However, only vitamin C, which can accumulate from 5 to 40 mg% in tubers, depending on the variety and growing conditions, has biological value. Ascorbic acid oxidises quickly and is quite sensitive to temperature, and therefore its amount is significantly reduced during heat treatment. In tubers of the varieties under study, the content of this element ranged within 8.9-11.4 mg%. Over 11 mg% of ascorbic acid was accumulated by fresh tubers of the Sante and Povin varieties. K. Hamouz *et al.* (2009) found that even the colour of tubers affects the content of this vitamin. The present study did not reveal such a pattern. Clearly, longer studies with more varieties are needed to confirm or refute this claim. As for the nitrate content, there was no significant difference between the variants, with an accumulation of 107-138 mg/kg. Tubers of Svitanok Kyivskyi and Povin varieties accumulated the most nitrates – 138 mg/kg. However, in none of the experimental variants did the actual nitrate levels exceed the MPC.

According to the previous findings of the authors of this study, the morphological characteristics of raw materials are also important for processing (Zavadska *et al.*, 2020). A. Mazur (2013) noted that the number of eyes in tubers suitable for processing should not exceed 7-8 and their depth should not exceed 1.5 mm. According to morphological parameters, tubers of all varieties under study met the requirements. The most suitable for processing in terms of the number of eyes were the Koroleva Anna (4.8 pcs.) and Povin (6.4 pcs.) tubers. The best performance in terms of the depth of the eyes was also achieved by tubers of the Koroleva Anna variety (0.57 mm) and Povin (0.87 mm). The amount of waste during tuber cleaning ranged within 15.0-23.3% and depended on the varietal characteristics (Fig. 2).

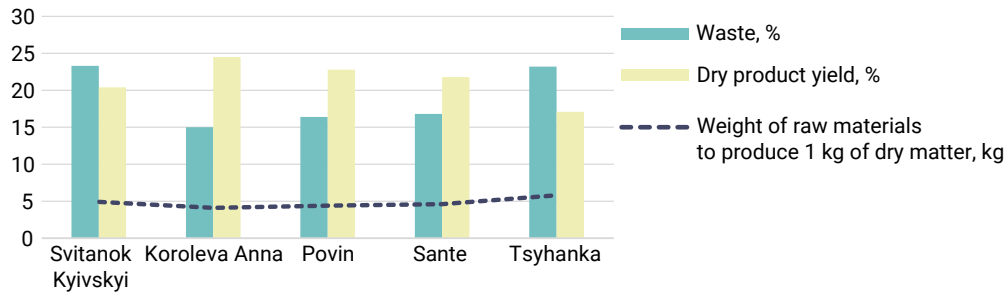

Figure 2. *Amount of waste, yield of dry products, and required weight of fresh raw materials to produce 1 kg of dry potato tubers of different varieties*

Note: * – control

Source: developed by the authors of this study

The largest amount of waste was obtained when cleaning tubers of Svitanok Kyivskyi (23.3%) and Tsyhanka (23.2%) varieties, while the smallest amount was obtained from Koroleva Anna (15.0%,

which is 8.3% less than in the control). This indicator was influenced by the number and depth of the eyes, as well as the presence of growths, mechanical damage, and pest damage. The yield of dried products significantly depended on the dry matter content of the raw materials and the amount of waste and ranged within 17.1-24.5%. Clearly, the largest amount of dry products was obtained from the Koroleva Anna variety tubers – 24.5%, which is 4.1% more than in the control variant. The calculations showed that 4.1 kg of fresh raw materials are required to produce 1 kg of dry products of this variety. The lowest yield of finished products was obtained using tubers of the Tsyhanka variety, which contained the lowest amount of dry matter – 17.1%, which is 3.3% less than the control. To produce 1 kg of dry products of this grade, 5.8 kg of raw materials were required. An important technological indicator of the quality of dried products, including potatoes, is their ability to recover, which is characterised by the swelling coefficient (Fig. 3).

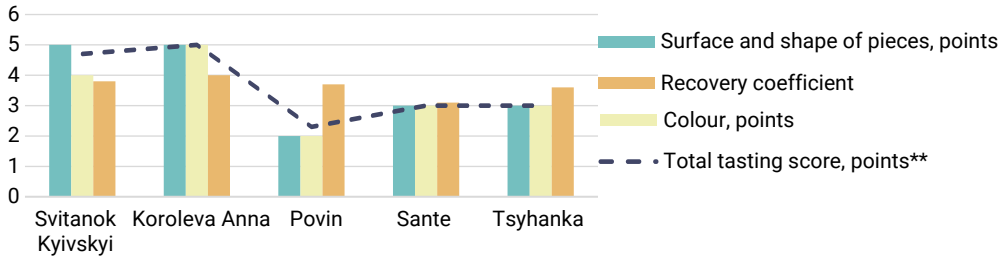

Figure 3. *Recovery factor, degree of darkening, and tasting evaluation of dried products from potato tubers of different varieties*

Note: * – control; ** – on a 5-point scale

Source: developed by the authors of this study

The results indicate that the best recovery rate was observed in samples of dry products of Koroleva Anna and Svitanok Kyivskyi varieties – the swelling coefficient was 4.0 and 3.8 units, respectively, the lowest was for the Sante variety (3.0). The most intensive recovery of dry products of all varieties occurred within 20 min from the beginning of soaking. To identify variants resistant to darkening of the flesh, the tubers were not blanched before drying. According to the study results, resistance to darkening significantly depended on the varietal characteristics. The most resistant to darkening without blanching before drying were the Koroleva Anna tubers. Dry and reconstituted products of this variety had a pleasant characteristic uniform cream colour, without darkening – 5 points (Fig. 4).

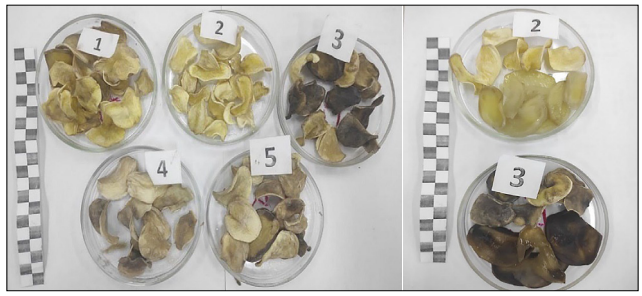

Figure 4. *General view of dried (A) and reconstituted (B) products from potato tubers of different varieties during tasting*

Note: 1 – Svitanok Kyivskyi; 2 – Koroleva Anna; 3 – Povin; 4 – Sante; 5 – Tsyhanka

Source: developed by the authors of this study

The organoleptic properties of dry and reconstituted products significantly depended on varietal characteristics, which is confirmed by C. Severini *et al.* (2010). Overall, the highest score in the finished product tasting was given to samples of the Koroleva Anna variety – 5.0 on a 5-point scale. The dry products of this grade were characterised by high resistance to darkening, fully retained the colour of the raw material, had a firm, elastic texture, and a uniform piece shape. During the tasting, the dry products of the control variety Svitanok Kyivskyi received quite high scores – 4.7 points on a 5-point scale. The least suitable for convection drying without blanching are Povin tubers. Dry samples of this variety received 2.3 points in the tasting. This low score was caused by the substantial darkening of dry and reconstituted products (1.8 points on a 5-point scale).

This study confirmed the findings of other researchers on the effect of sugar content in tubers on the degree of darkening of dry products, which is apparently caused by their interaction with amino acids and the formation of melanins (Bobo-García *et al.*, 2020; Hussain *et al.*, 2022), The correlation analysis revealed a significant direct relationship between these indicators – r = 0.74.

Thus, the findings of the present study suggest that the choice of potato variety substantially affects the quality of dry products and the efficiency of their production. The most suitable tubers for drying are those that accumulate the maximum amount of dry matter and starch, the minimum amount of sugars, have a small number of shallowly set eyes, and are highly resistant to darkening during heat treatment.

Conclusions

It was found that during the growing season, different amounts of reserve substances were accumulated in potato tubers of different varieties under the same growing conditions. The highest amount of dry matter and starch was contained in tubers of the Povin variety – 24.6% and 18.4%, respectively. The correlation analysis revealed a strong direct correlation between these indicators – r = 0.98. The dry matter content substantially influenced the yield of dried potatoes.

The amount of nitrates in the tubers of all the variants under study did not exceed the MPC and was even substantially lower than the established norm. The lowest amount of nitrates was accumulated in tubers of the Tsyhanka variety during the growing season – 107 mg/kg. There was no effect of varietal characteristics on nitrate accumulation.

The number of eyes and their depth also depended on the variety characteristics and affected the amount of waste and dry product yield. The smallest number of eyes was formed by tubers of Koroleva Anna and Povin varieties – 4.8 pcs./tuber and 6.4 pcs./tuber, respectively. The depth of their occurrence in tubers of these varieties was the smallest. The lowest waste in preparing tubers for drying and the highest yield of finished products were found in these variants – the amount of waste was 15.0% and 16.2%, and the yield of dry products was 24.5% and 22.8%, respectively. The calculations revealed that to produce 1 kg of dry products of these varieties, 4.1 kg and 4.4 kg of fresh raw materials are required.

The dry and reconstituted pieces made from Povin tubers were the most prone to darkening and upon tasting received 2.3 points and 1.8 points on a 5-point scale, respectively. When using tubers of this variety for convection drying, blanching, or other methods should be used to prevent discolouration.

Dry products from Koroleva Anna and Svitanok Kyivskyi tubers had the best recovery rate, with a swelling coefficient of 4.0 units and 3.8 units, respectively. The most intensive recovery process occurred within 20 min after soaking.

Thus, according to the complex of studied indicators, the most suitable for convective drying without blanching are tubers of the Koroleva Anna variety, which accumulate 23.1% dry matter, 17.6% starch, and 0.32% sugars during the growing season. The amount of waste when using tubers of this variety will be 15%, the yield of dry products will be 22.8%, and its tasting score will be 5.0 points on a 5-point scale.

Further research can be aimed at identifying the impact of growing conditions on the quality of fresh tubers and dry products, as well as improving drying technologies, specifically, investigating the impact of drying methods and temperatures.

Acknowledgements

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Conflict of Interest

None.

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Придатність бульб картоплі різних сортів до переробки

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Анотація. Сушіння – один з найпоширеніших способів переробки бульб картоплі. Для отримання якісної сушеної продукції вирішальне значення має якість сировини, яка суттєво залежить від сортових особливостей. Метою дослідження було вивчення придатності бульб картоплі п'яти сортів до конвективного сушіння без проведення бланшування. Під час проведення досліджень було використано метод експерименту, згідно з розробленою схемою досліджень, лабораторний метод – для визначення органолептичних, морфологічних і біохімічних показників якості свіжих бульб та сухої продукції, статистистичний – для математичної обробки результатів досліджень. Виявлено, що найбільше сухої речовини та крохмалю містили бульби сорту «Повінь» – 24,6 та 18,4 % відповідно, а вітаміну С – «Санте» та «Повінь» (понад 11 мг%). Найменше цукрів накопичувалося у бульбах сорту «Королева Анна» – 0,32 %. Виявлено, що зі збільшенням вмісту в бульбах сухої речовини суттєво зростає вміст крохмалю (r = 0,98), а вміст цукрів істотно впливає на ступінь потемніння сухої продукції (r = 0,74). Вміст нітратів бульбах всіх сортів не перевищував гранично допустимої концентрації. Встановлено, що при використанні для конвективного сушіння бульб картоплі можна отримати 17,1-24,5 % сухої продукції й витратити 4,1-5,8 кг підготовленої сировини. На вихід готової продукції суттєво впиває вміст сухої речовини у бульбах та кількість відходів. Найпридатнішими для конвективного сушіння без проведення бланшування є бульби сорту «Королева Анна», використання яких забезпечить вихід готової продукції на рівні 24,5 % з дегустаціної оцінкою 5 балів за 5-ти бальною шкалою. При використанні для конвективного сушіння бульб інших досліджуваних сортів необхідно попередньо проводити бланшування чи застосовувати інші способи для стабілізації забарвлення. Матеріали статті становлять практичну цінність для овочівників, селекціонерів, фахівців переробних підприємств під час вибору сорту картоплі для сушіння

Ключові слова: сортові особовості; якість, дегустація; потемніння; сушіння; суха продукція