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Pumpkin fruit selection of different types and varieties for the production of functional food products

Abstract. Consumers in Ukraine and around the world are increasingly interested in healthy lifestyles and functional foods with high biological value. For the production of such foods, it is important to select raw materials that meet a range of quality requirements. Pumpkin fruits have a high content of nutrients, vitamins, essential amino acids, and minerals that largely meet these requirements. The research aims to comprehensively evaluate pumpkin fruits of eight varieties of

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different types: large-fruited (*Cucurbita maxima* Duch) and butternut (*Cucurbita moschata* Duchex Poir), grown in the forest-steppe of Ukraine, to identify the most suitable for drying and production of functional foods. The experimental method was used following the research plan, the laboratory method was used to determine biochemical, biometric, and organoleptic quality indicators, and the statistical method was used to conduct dispersion and correlation analyses of the studied indicators. It has been established that when large-fruited pumpkin varieties are used for convective drying, 16.1-20.3% of dry products with a sugar content of 48.6-51.6% and 11-14 and 34.5-40.2% of nutmeg varieties, respectively, can be obtained. For the production of functional food products with a β -carotene content of 40-41 mg/100 g (in terms of dry matter), it is advisable to use the fruits of nutmeg varieties Gilea and Divo, and vitamin C at the level of 28 mg% – large-fruited varieties Slavuta and Polyovychka. The study revealed that with the increase in fruit weight, the content of dry matter ($r=-0.68$), sugars ($r=-0.67$) and the yield of finished products ($r=-0.74$) significantly decreases. A significant direct relationship between the content of dry matter and sugars ($r=0.98$), as well as the content of dry matter and the yield of finished products ($r=0.94$), was established. The materials of the article are of practical value for breeders, vegetable growers, and specialists of processing enterprises when choosing a type and variety of pumpkin for the production of functional foods

Keywords: quality; vitamin C; carotene; processing; drying; raw materials

INTRODUCTION

The research relevance of pumpkin fruit is determined by the growing interest in functional foods, especially in the context of the growing attention to a healthy lifestyle. The study of their medicinal and antioxidant properties can contribute to the development of new products to maintain health and prevent diseases, which is especially important in the context of the impact of various negative factors on the health of modern Ukrainians, such as stressful situations, the COVID-19 pandemic, fast pace of life and climate change. Such research is essential for providing quality and healthy food products to consumers and maintaining their health in the modern world (Kaur et al., 2020).

In ancient times, Hippocrates expressed the well-known idea that food should be medicine and medicine should be food. This is the principle that guides manufacturers of functional foods. Today, many countries around the world have government programmes to create them. Functional foods are foods for systematic consumption that, in addition to nutrients, contain ingredients that, when consumed regularly, have a positive effect on the body, help to adapt to adverse environmental conditions and strengthen the immune system (Hussain et al., 2022). They have a wide range of health effects, including cardioprotective, hypoglycaemic, antioxidant,

anticancer, antibacterial, immunomodulatory, neuroprotective, and anti-inflammatory effects, and prevent the development of cardiovascular and oncological diseases (Djiogue et al., 2018; Villamil et al., 2023). The properties of such products are determined primarily by the biological and biochemical compounds that make up their composition. V. Khareba et al. (2019) noted that the development and production of functional foods is “the only way to solve the global problem of optimising nutrition, maintaining health and prolonging human life”.

Pumpkin fruit is an important food product with high nutritional and biological value, antioxidant and medicinal properties, and raw materials suitable for the production of products with functional properties (Sharma et al., 2020; Koprualan et al., 2021). The medicinal properties of pumpkin have been known since ancient times. The ancient Greek physician Diogenes mentioned them in the first century AD, and Ibn Sina, better known as Avicenna, described them in detail in his medical treatises. P. Ramachandran et al. (2022) used pumpkin pulp, seeds, and oil in their research to make medicines. The use of pumpkin pulp as a natural pigment in powder form added to confectionery, bakery, pasta, and dairy products is a fairly new area of processing. These inexpensive powders

from pumpkin fruit can be used as a potential source for the production of functional foods and nutraceuticals in the food and healthcare industry (İzli *et al.*, 2022).

The research aims to comprehensively evaluate pumpkin fruits of different varieties and species (*Cucurbita maxima* Duch and *Cucurbita moschata* Duchex Poir) grown in the forest steppe of Ukraine to identify the most suitable for drying and production of functional foods.

LITERATURE REVIEW

A growing interest in pumpkin cultivation in Ukraine, especially for the production of seeds and oil using Styrian hybrids (*Cucurbita pepo* styriaca) can be noted. However, pumpkin fruit is also used to create a wide range of healthy, nutritious, and functional food products, which include juices, soups, cereals, chips, cookies, bread, cakes, bars and noodles (Rózyło *et al.*, 2014). The flesh is used for various types of processing: stewed, boiled, baked, dried, pickled, frozen, mashed, chips, caviar, porridge, soups, jams, jams, candied fruits, juices, smoothies, etc. (Hussain *et al.*, 2022). The fruits of table pumpkins, which include large-fruited (*Cucurbita maxima* Duch) and butternut (*Cucurbita moschata* Duchex Poir) species, are mostly used for food processing. These are the types of pumpkins used in the research.

The biologically valuable and medicinal properties of pumpkin fruits are determined by the rich chemical composition of the pulp and seeds. Pumpkin mesocarp contains 78-92% water, and 4-12% sugars, starch is almost absent in some varieties, and in others, it reaches 5%; the content of pectin substances is 2.6-3.9%; fibre is 0.5-1.3%, 0.2-10%, about 1% proteins, 0.1% organic acids. The pulp also contains a significant number of vitamins, mg/100 g: B₃ – 0.3-0.4, B₆ – 0.10-0.12, B₉ – 14.0-14.2, E – 0.3-0.5, PP – 0.5-0.7, vitamin C – 8-25 and β -carotene 6-35, micro- and trace elements (Hussain *et al.*, 2022). B. Kulczynski & A. Gramza-Michałowska (2019) note that the most common minerals in pumpkin pulp were potassium, calcium, and sodium. The fruit is characterised by low-calorie content (21-30 kcal/100 g) and is widely used in various diets. Pumpkins with orange flesh are especially valuable because they are high in carotenoids, especially β -carotene and lutein.

Pumpkin seeds contain about 20% of oil, which is used as an effective anthelmintic and diuretic for heart disease, kidney disease, hypertension, and cholecystitis (Ahmed *et al.*, 2022). Pumpkin seeds contain 92% of dry matter, %: dry protein – 41.85; crude lipids – 45.35; crude fibre – 1.95; ash – 4.7; extractives – 6.15; calcium – 0.55; phosphorus – 1.12 (Hussain *et al.*, 2022). Pumpkin seed oil is valued for its high content of fatty polyunsaturated acids, %: myristic – 12.0; palmitic – 15.9; stearic – 8.7; oleic – 41.0; linoleic – 34.3; linolenic – traces. Such a complex of acids has antioxidant properties, stimulates fat metabolism in the human body, binds cholesterol into a form easily absorbed in the body, and prevents it from settling on the walls of blood vessels, thereby preventing the development of cardiovascular diseases (Kulczynski & Gramza-Michałowska, 2019; Ahmed *et al.*, 2022). M.A. Gedi (2022) found that phenolic compounds, fatty acids, tocopherols, minerals, and carotenoids contained in pumpkin oil are involved in lowering cholesterol levels, and have anticarcinogenic, anti-inflammatory, anti-diabetic, and antimicrobial effects. Thanks to their excellent oxidative stability, pumpkin seed cake-based films prevent lipid oxidation in food products and can be successfully used for their packaging (Hromis *et al.*, 2022).

Drying is a promising method of processing pumpkin pulp, as it preserves biological valuable elements contained in fresh raw materials (Seifu *et al.*, 2018). Dried pumpkin is produced in the form of pieces, cubes, strips, granules, and powder. Dry pumpkin powder, as a concentrate of fibre, minerals, and vitamins, is used as a natural dietary supplement to improve organoleptic characteristics, increase their biological value and antioxidant properties (Indrianti *et al.*, 2021). The main effect of adding pumpkin dry powder on the physicochemical properties of bakery products, dairy products, beverages, and snacks is to increase the energy, protein, iron, calcium, and carotene content and improve textural properties (hardness, chewiness, tensile strength, and viscosity) (Villamil *et al.*, 2023).

Air-solar, convective, microwave, infrared, freeze-drying, or a combination of these are used to dry pumpkin fruit. To maximise the preservation of biologically active components in

pumpkin chips, it is most advisable to use a combination of freeze-drying and microwave drying (Koprualan *et al.*, 2021). E. Chao *et al.* (2022) note that drying pumpkin pulp with infrared radiation allows for preserving the highest polyphenol content and the ability to scavenge free radicals. Blanching the raw materials before drying and using the freeze-drying method minimises the loss of carotenoids, consistency, taste, and colour of the finished product (Kaur *et al.*, 2020).

Convective drying with heated air remains one of the most common methods of drying vegetables, including pumpkins. According to S. Chikpah *et al.* (2022), the quality of dry pumpkin products during air convection drying depends on the thickness of the particles and air temperature. The content of β -carotene and ascorbic acid was higher in pumpkin dried at 60°C than at 50°C and 70°C. To increase the biological value and organoleptic characteristics of dried pumpkin products G. İzli *et al.* (2022) recommend combining convective drying with microwave drying.

MATERIALS AND METHODS

The research was conducted in 2014–2015 at the National University of Life and Environmental Sciences of Ukraine. The experimental crops were grown on the plots of the Agronomic Experimental Station of the National University of Life and Environmental Sciences of Ukraine, a separate subdivision of the National University of Life and Environmental Sciences of Ukraine, using the technology generally accepted in production. The farm is located in the right-bank forest-steppe zone of Ukraine. The soil of the site is typical low-humus black soil. The climate of the zone is moderately continental with moderately cold winters and rather warm summers. According to long-term data, the annual air temperature is 7.1°C. The average long-term temperature of the coldest month (January) is -6.8°C, and the warmest month (July) is +19.9°C. The sum of active temperatures above 10°C is in the range of 2500–2800°C.

Precipitation in this zone is high, with an annual rate of 550–600 mm. Most of the precipitation falls in summer in the form of rain. In the years of the study, the amount of precipitation during the growing season was 120–154 mm

higher than the average long-term data. In general, the soil and climatic conditions of the zone are favourable for growing pumpkins and obtaining a quality harvest.

Eight varieties of Ukrainian production were selected for the experiment, in particular: four varieties of large-fruited pumpkin (Zhdana, Slavuta, Yubilee of the Dnipro Experimental Station and Polevychka of the Southern Institute of Vegetable and Melon Production), and four varieties of butternut pumpkin (Gilea, Divo, Yanina of the Southern Institute of Vegetable and Melon Production and Dolya of the Dnipro Experimental Station). The large-fruited pumpkin variety Polevychka and the butternut pumpkin variety Gilea, which are listed in the Register of Plant Varieties and are common in production, were used as controls (n.d.).

Biometric, organoleptic, and biochemical parameters were determined in the educational and scientific laboratory of the Lesyk Department of Technology of Storage, Processing and Standardisation of Plant Production according to generally accepted methods (Skaletska *et al.*, 2014). To determine the biometric parameters of the ratio of bark, seeds, and pulp, five typical fruits of each variant were selected in triplicate. The dry matter content was determined according to the requirements of DSTU ISO 751:2004 (2005); thermogravimetric analysis by drying in an oven at a temperature of 100–105°C to a constant weight; dry soluble matter – using a refractometer by the requirements of DSTU ISO 2173: 2007 (2009); sugar content (total) – by Bertrand according to DSTU 4954:2008 (2009); β -carotene – by photometric method according to DSTU 4305:2004 (2005); vitamin C – using a solution of 2,6 dichlorophenolindophenol. The organoleptic evaluation was carried out by tasting baked pieces, dry and reconstituted pumpkin products on a 9-point scale.

For drying, 3 kg of fresh pumpkin fruit was selected in 3 replicates, cut into segments, weighed, washed, and peeled from the bark, seeds, and fibrous part; the difference between before and after cleaning was used to determine the amount of waste. The prepared raw materials were cut into strips of the following sizes using a mechanical chopper SIRMAN (Italy): length 5–6 mm, width 2–3 mm, thickness 2–3 mm. The

resulting strips were evenly placed on dryer pallets at a rate of 3 kg/m² and loaded into a pre-heated chamber. For drying, a convective batch-type dryer “Sadochok 2M” (Ukraine) was used. The products were dried at a temperature of 60°C until they were completely dry. This drying temperature ensures maximum preservation of organoleptic characteristics and biologically valuable substances (Chikpah *et al.*, 2022). The yield of the finished product was converted to a standard moisture content of 10%.

The research results were processed mathematically, confidence intervals, the smallest significant difference, and correlations between the studied indicators were determined using generally accepted methods. The strength of the relationship was assessed according to the

following gradation: if r (correlation coefficient) was equal to 1, the calculated relationship between the attributes was complete; if r was 0.66–0.99, the relationship was strong (significant); if r was in the range of 0.33–0.65, the relationship was medium; if r was less than 0.33, the relationship was weak, insignificant. The study was conducted following the requirements of the Convention on Biological Diversity (1992) and the Convention on International Trade in Endangered Species of Wild Fauna and Flora (1973).

RESULTS AND DISCUSSION

The research results indicate that the ratio of morphological components of pumpkin fruit is genetically determined, depending on both the botanical variety and the species (Fig. 1).

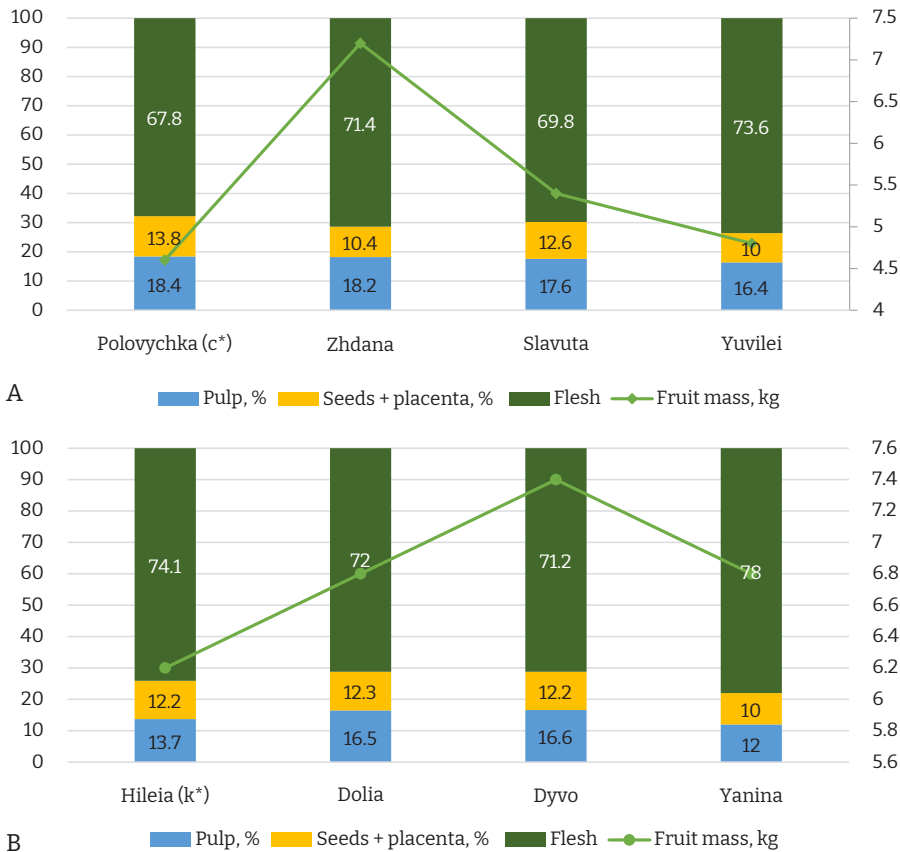


Figure 1. Average fruit weight and ratio of morphological parts of pumpkin fruit (average for 2013–2014)

Note: A – varieties of large-fruited pumpkin; B – varieties of butternut pumpkin; * control

Source: compiled by the authors

Fruit weight is a variable indicator that significantly depends not only on varietal characteristics but also on soil and climatic conditions and cultivation technology. The fruit weight of large-fruited pumpkins can vary from 1 to 60 kg or more (Khareba & Kokoiko, 2022). It was found that plants of butternut pumpkin varieties formed heavier fruits in weight compared to large-fruited ones. Thus, the average fruit weight of large-fruited pumpkins ranged from 4.6-7.2 kg (the average for the group was 5.5 kg), and that of nutmeg pumpkins – 6.2-7.4 kg (the average was 6.7 kg). Among the large-fruited varieties, the largest fruits were in plants of Zhdana variety – 7.2 kg, which is 2.6 kg more than in the control (significant difference), and among the nutmeg varieties – in Divo variety 7.4 kg, which is significantly more than in the control variety. In general, the weight of 1000 seeds were higher in the fruits of large-fruited varieties (average value 284.8 g), and significantly lower in nutmeg varieties – an average of 136.8 g.

Nutmeg pumpkin fruits varieties (*Cucurbita moschata* Duch) had a higher pulp content (71.2-78.0%), and lower bark content (12.0-16.5%) compared to large-fruited varieties (*Cucurbita maxima* Duch). The content of the soft part in the fruits of large-fruited varieties ranged from 67.8-73.6%, the share of bark – 16.4-18.4%, and seeds

with placenta – 10-13.8%. The Zhdana and Yubilei varieties stood out among large-fruited pumpkins in terms of pulp content – 71.4 and 73.6%, respectively, and among butternut squash – Yanina and Gilea (control) – 78 and 74.1%, respectively. The fruits of large-fruited pumpkin varieties Polevychka (67.8%) and Slavuta (69.8%) contained the least amount of pulp.

Thus, the formation of morphological features of pumpkin fruit, which determine its quality, physical characteristics, anatomy and cell structure, content and ratio of morphological parts depends on the type and varietal characteristics. The Zhdana and Yubilee varieties stood out among the large-fruited species in terms of indicators that characterise marketability and suitability for processing, and the Janina and Gilea varieties (control) among the nutmeg varieties. The pulp content in the fruits of these varieties exceeded 70%.

Evaluation of pumpkin fruit quality by biochemical parameters is relevant, as its chemical composition and flavour properties significantly affect its suitability for processing and the quality of finished products. In addition, the content of carotene and vitamin C determines their biological value and the possibility of using them for the production of functional foods. The results of the study are shown in Table 1.

Table 1. The content of the main elements of the biochemical composition of fresh pumpkin pulp and tasting score, depending on the type and variety, average for 2014-2015

Variety	Flesh contents					Taste test, mark**
	dry matter, %	of dry soluble matter, %	sugars (sum), %	β-Carotene, mg/100 g	vitamin C mg %	
Large-fruited (<i>Cucurbita maxima</i> Duch)						
Polovychka (control)	14.3±0.5*	12.2±0.2	7.9±0.3	7.2±1.2	15.2±0.8	8.1±0.3
Zhdana	13.4±0.4	11.3±0.2	7.4±0.3	9.4±1.1	14.8±2.1	7.4±0.2
Slavuta	14.5±0.6	12.3±0.1	8.0±0.4	7.6±0.8	17.4±1.2	7.8±0.3
Yuvilei	13.6±0.4	11.6±0.1	7.6±0.2	8.8±0.6	12.5±1.4	7.5±0.2
Nutmeg (<i>Cucurbita moschata</i> Duch)						
Hileia (control)	10.4±0.5	9.0±0.2	6.3±0.2	15.8±1.2	6.7±0.5	8.4±0.2
Dolia	10.2±0.4	8.8±0.1	6.1±0.1	12.4±1.5	7.5±0.8	8.5±0.2
Dyvo	9.3±0.6	8.2±0.1	5.5±0.1	14.2±0.4	9.8±1.0	7.8±0.3
Yanina	9.8±0.6	8.4±0.2	5.6±0.2	13.5±0.5	8.0±0.4	7.6±0.2

Note: *biochemical parameters are mean values ± standard deviation (n=3); **on a 9-point scale

Source: compiled by the authors

During the vegetation period, the fruits of large-fruited pumpkin (*Cucurbita maxima* Duch) accumulated 13.4-14.5% of dry matter (the average value in the group was 14.2%). Most of them were contained in pumpkins of the Slavuta variety – $14.5 \pm 0.6\%$, and significantly less, compared to the control, in the fruits of the Zhdana variety – $13.4 \pm 0.4\%$. There was no significant difference in dry matter content between the Slavuta and Polyovychka (control) varieties. The dry matter content of butternut squash (*Cucurbita moschata* Duch) was significantly lower in them compared to large-fruited varieties and ranged from 9.3-10.4% (average in the group 9.9%). The fruits of the Gilea (control) and Dolya varieties contained the highest amount of dry matter – 10.4 ± 0.5 and $10.2 \pm 0.4\%$, respectively. The dry soluble matter was also higher in the fruits of large-fruited pumpkins – 11.3-12.3%. Among the nutmeg pumpkin varieties, the fruits of Gilea (control) and Dola varieties contained the highest amount of dry soluble matter – 9.0 ± 0.2 and $8.8 \pm 0.1\%$, respectively.

The total sugar content ranged from 5.5 ± 0.1 in the fruits of nutmeg varieties to $8.0 \pm 0.4\%$ in large-fruited varieties. Their higher content, as well as dry matter, was in the fruits of large-fruited pumpkin varieties – from 7.4 ± 0.3 to $8.0 \pm 0.4\%$. The fruits of the Slavuta variety accumulated the most sugars among the studied varieties during the growing season – $8.0 \pm 0.4\%$. At the same time, monosaccharides prevailed in the composition of sugars in the fruits of large-fruited pumpkins. Muscat pumpkin varieties accumulated 5.5-6.3% of sugars (total). They did not show a predominance of monosaccharides, and sucrose prevailed in the fruits of the Divo and Yanina varieties. Among the butternut pumpkin varieties, the Gilea (control) and Dolya varieties stood out in terms of sugar content, with 6.3 ± 0.2 and 6.1 ± 0.1 , respectively.

B. Kulczynski & A. Gramza-Michałowska (2019) noted that the content of carotenoids, which are the main biologically valuable components in fresh pumpkin fruits, depends on the variety and degree of ripeness. Our research confirmed their data and showed that the content of β -carotene depends on both the variety and the botanical type of pumpkin. Thus, in terms of β -carotene content, the fruits of the nutmeg

varieties Gilea and Divo prevailed – 15.8 ± 1.2 and 14.2 ± 0.4 mg/100 g, respectively. The fruits of large-fruited varieties contained much less of this element – 7.2-9.4 mg/100 g.

As noted by M. Ouyang *et al.* (2022), the biological value of fruit and vegetable products also depends on the vitamin C content. It plays a positive role as an antioxidant, can protect the body from viral infections and strengthen the immune system. The above-mentioned researchers claim that the content of ascorbic acid in fruit and vegetables significantly depends on varietal characteristics. Similar data were obtained in their research with onion bulbs (Zavadzka *et al.*, 2021). Studies with pumpkin fruits have shown that, in addition to varietal characteristics, the content of vitamin C, like β -carotene, also depends on the botanical species. However, while β -carotene was higher in pumpkin fruits of nutmeg varieties, vitamin C, on the contrary, was higher in large-fruited pumpkins. Thus, the content of this element in the fruits of pumpkin varieties of nutmeg was in the range of 6.7-9.8 mg%, and large-fruited – 12.5-17.4 mg%. Fresh fruits of large-fruited pumpkin of Slavuta and Polyovychka varieties (control) contained the most vitamin C – 17.4 ± 1.2 and 15.2 ± 0.8 mg%, respectively.

The nitrate content in the fruits of the studied varieties did not exceed the maximum permissible level (200 mg/kg). A greater amount of nitrates was accumulated in the fruits of nutmeg varieties, in particular, the highest amount was found in the fruits of the Dolya variety (123 mg/kg). In the fruits of large-fruited varieties, nitrates accumulated on average from 66.5 to 82 mg/kg. The lowest amount was in the fruits of the Zhdana variety (66.5 mg/kg).

Thus, the content of the main biochemical parameters in pumpkin fruits of the studied varieties differed significantly and depended more on the species than on the variety. The fruits of large-fruited varieties accumulated a greater amount of dry matter (13.4-14.5%), dry soluble matter (11.3-12.3%), sugars (7.4-8.0%) and vitamin C (12.5-17.4 mg%). Large-fruited varieties prevailed in terms of β -carotene content, with the amount ranging from 12.4-15.8 mg/100 g.

Studies on the suitability of pumpkin fruit for drying are relevant, as this processing method allows for the production of biologically

valuable products. Previous studies have shown that the quality, amount of waste, and yield of dry carrot and onion products are significantly affected by varietal characteristics (Zavadska et al., 2020; 2021). Similar data were obtained

when studying the suitability of pumpkin fruit for this processing method. In addition to varietal characteristics, the yield and quality of finished pumpkin products were also influenced by their type (Fig. 2).

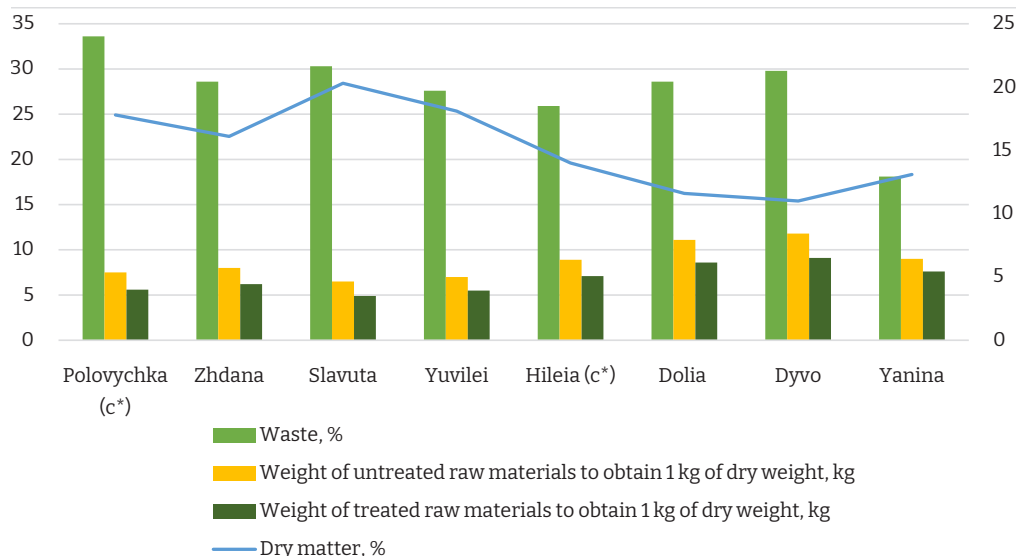


Figure 2. Amount of waste, the yield of dry products and the required weight of fresh raw materials to produce 1 kg of dry pumpkin fruit of different types and varieties, average for 2014-2015

Note: *control

Source: compiled by the authors

The total amount of waste in the process of preparing raw materials for drying varied significantly and ranged from 18.1-33.6%. Waste included bark, placenta, and seeds, which were removed during cleaning. The largest amount of them was in large-fruited pumpkin varieties – 27.6-33.6%, which is due to the ratio of morphological components of the fruit. In the fruits of large-fruited varieties, the bark, placenta, and seeds occupy a larger part compared to nutmeg (see Fig. 1). Among large-fruited varieties, the lowest amount of waste was in the Yubilee variety – 27.6%, and among nutmeg varieties – in the Yanina variety – 18.1%, which is 7.8% less than in the control (significant difference).

The yield of dried products was calculated at a standard 10% moisture content. More dry products could be obtained from large-fruited pumpkin varieties – 16.1-20.3%. Among the studied varieties, pumpkin fruits of the Slavuta

variety stood out by this indicator – the yield of dry products was 20.3%, which is 2.5% more than in the control. From pumpkin fruits of nutmeg varieties, it was possible to obtain 11-14% of dry products, the highest yield was obtained using the Gilea variety (control). No significant difference was found between the varieties Dolia and Divo in terms of finished product yield.

Based on the aforementioned data, 6.5-11.8 kg of fresh unpeeled fruit or 4.9-9.1 kg of peeled fruit was required to produce 1 kg of dried product. Less raw materials were consumed when large-fruited pumpkin varieties were used for drying. The Slavuta variety stood out by this indicator. If the fruit of this variety is used for drying, 6.5 kg of unpeeled fruit or 4.9 kg of peeled fruit is required to produce 1 kg of dry product.

For consumers of dried and reconstituted pumpkin products, the content of biochemical parameters in them is of great importance (Fig. 3).

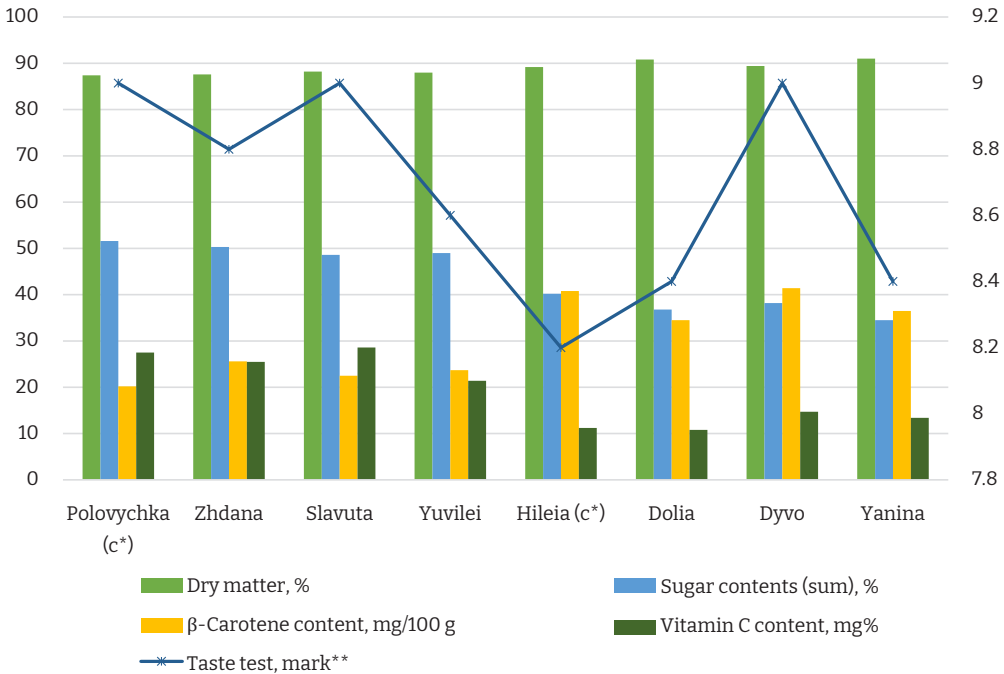


Figure 3. The content of the main biochemical parameters (in terms of dry matter) and tasting evaluation of dried pumpkin products of different types and varieties, average for 2014-2015

Note: * control ** on a 9-point scale

Source: compiled by the authors

According to the results of the research, dried pumpkin products are a concentrate of dry matter, as they contain 87.4 to 91% of it, which is on average 6.3-8.4 times higher than the content in the raw material. The samples of dry products made from large-fruited pumpkin varieties had more dry matter – 11.6-12.8%. This is due to the higher content of sugars that bind moisture in dried products. During the research on the suitability of onion varieties for drying, it was found that the sugar content in dried products in some variants even increased compared to fresh raw materials (by 1.2%). This indicates that during the drying process, poly sugars can be converted to mono- and disaccharides (Zavadska *et al.*, 2021). Regarding dry pumpkin products, more sugars (total) were found in samples of large-fruited varieties (48.6-51.6%) compared to nutmeg varieties (34.5-40.2%). The highest number of sugars (total) was found in the dry products of large-fruited varieties Polovychka (control) and Zhdana – more than 50%.

Based on the literature, dried pumpkin products contain a fairly significant amount of

β-carotene and vitamin C, substances that determine the biological value and suitability of raw materials for the production of functional foods (Sharma *et al.*, 2020; Ouyang *et al.*, 2022). According to A. Hussain *et al.* (2022), due to the presence of significant amounts of functional ingredients, the use of dried pumpkin products has a wide range of applications. Our research has confirmed the presence of a significant amount of β-carotene (202-41.4 mg/100 g) and vitamin C (10.8-28.6 mg%) in dry pumpkin products, which gives grounds to recommend them as raw materials for the production of functional foods.

S. Chikpah *et al.* (2022) found that the content of β-carotene and ascorbic acid in dry pumpkin products also depends on the drying temperature and the thickness of the slices. Thus, the amount of β-carotene in dry samples in their studies ranged from 43.8-58.15 mg/100 g, and vitamin C – from 37.62-50.13 mg/100 g. More of these biologically active components were found in products dried at 60°C with a slice thickness of 3 mm than at 50°C and 70°C with

a slice thickness of 5 mm – 58.15 ± 1.75 mg/100 g of β -carotene and 50.13 ± 2.03 mg/100 g of vitamin C. An increase in the thickness of the pumpkin slice prolonged the drying time and caused a more significant loss of bioactive compounds and antioxidant activity of dry products. The lower values of β -carotene in pumpkins dried at air temperatures below and above 60°C may be due to longer drying time at lower drying temperatures and thermal degradation at higher temperatures (Chikpah *et al.*, 2022).

During the convective drying of pumpkin strips 5-6 mm long and 2-3 mm thick at a temperature of $+60^\circ\text{C}$, the content of β -carotene ranged from 20.2-41.4 mg/100 g, and vitamin C – 10.8-28.6 mg% and significantly depended on the type of pumpkin. In terms of β -carotene content, dry samples of butternut pumpkin varieties significantly exceeded large-fruited varieties and contained 34.5-41.4 mg/100 g (large-fruited varieties – 20.2-25.6 mg/100 g). By the content of this biologically valuable component, the varieties of butternut squash Divo and Gilea stood out – more than 40 mg/100 g. However, in the dry products of large-fruited pumpkins, a significantly higher content of vitamin C was found compared to nutmeg pumpkins – 21.4-28.6 mg% (in nutmeg pumpkins – 10.8-14.7 mg%).

During the convective drying of pumpkin at a temperature of $+60^\circ\text{C}$, it was found that there was a significant loss of biologically valuable substances compared to fresh raw materials, which confirms the data of other researchers and our previous studies. The recalculations revealed that the loss of vitamin C during drying was more significant than that of β -carotene and amounted to 56-70% depending on the variety, while that of β -carotene was 36-40%. According to S. Chikpah *et al.* (2022), the decrease

in the content of β -carotene and vitamin C during drying can be attributed to oxidative and thermal degradation, as well as their isomerisation due to exposure to oxygen, heat and light during drying. Similar losses of vitamin C and β -carotene were observed in our studies on the suitability of carrot and onion roots for drying (Zavadska *et al.*, 2020; Zavadska *et al.*, 2021). According to A. B. Armand *et al.* (2018), the loss of vitamin C during the convective drying of onions was 72.5-78.1%. In these studies, on the suitability of onions for drying, the loss of this biologically valuable element depended on the variety and ranged from 48-60% (Zavadska *et al.*, 2021).

The experimental samples of all varieties received high scores during the tasting – 8.2-9.0 points on a 9-point scale. They had a crispy texture, intense uniform colour, and a pleasant taste. In the samples of dried products of nutmeg varieties Dolya and Yanina, the taste was less intense, which is why the scores were slightly lower – 8.2-8.4 points. A direct significant correlation was found between the sugar content and the tasting score of dried products ($r=0.69$).

Thus, dried pumpkin products are a biologically valuable substance suitable for the production of functional foods, as they contain from 20.2 to 41.4 mg/100 g of β -carotene and 10.8-28.6 mg/100 g of vitamin C. To do this, we recommend using the fruits of the nutmeg varieties Divo and Gilea, whose dry products contain more than 40 mg/100 g of β -carotene, and the large-fruited Slavuta and Polevichka, whose vitamin C content is 28.6 and 27.5 mg/100 g, respectively.

Correlation relationships were calculated between the studied quality indicators of fresh fruits and dry pumpkin products, the results of which are presented in Table 2.

Table 2. Matrix of correlation relationships between the studied indicators of pumpkin (calculated using average values)

Indicator	Fruit mass, kg	Flesh contents, %	Dry matter, %	Sugar contents, %	Carotene content, mg/100 g	Vitamin C content, mg/100 g	Dry matter, %	Tasting evaluation of dry products, points
Fruit mass, kg	1							
Flesh contents, %	0.45	1						
Dry matter, %	-0.68*	-0.66	1					

Table 2. Continued

Indicator	Fruit mass, kg	Flesh contents, %	Dry matter, %	Sugar contents, %	Carotene content, mg/100 g	Vitamin C content, mg/100 g	Dry matter, %	Tasting evaluation of dry products, points
Sugar contents, %	-0.67*	-0.71*	0.98*	1				
Carotene content, mg/100 g	0.65	0.58	-0.73*	-0.87*	1			
Vitamin C content, mg/100 g	-0.41	-0.72*	0.84*	0.85*	-0.58	1		
Dry matter, %	-0.74*	-0.51	0.94*	0.92*	-0.54	0.62	1	
Tasting evaluation of dry products, points	-0.18	-0.76*	0.52	0.69*	-0.54	0.64	0.42	1

Note: *a strong correlation exists between the attributes

Source: based on own research

The calculations of correlation dependence revealed an inverse significant relationship between fruit weight and dry matter content ($r=-0.68$), sugar content ($r=-0.67$) and dry product yield ($r=-0.74$). The obtained results confirm the data of other researchers, namely: with an increase in fruit weight, the content of dry matter, sugars and dry product yield significantly decreases; smaller fruits contain more dry matter and sugars. Fruit weight did not significantly affect the content of carotene and vitamin C, as well as the tasting evaluation of dry products. A similar pattern was found between the pulp content and biochemical parameters: with an increase in the amount of pulp in the fruit, the content of dry matter ($r=-0.66$), sugars ($r=-0.71$) and vitamin C ($r=-0.72$) significantly decreased, and the tasting score of dry products worsened ($r=-0.76$). A significant direct relationship between the dry matter content and the yield of finished products was established ($r=0.94$).

Significant correlations were found between the biochemical parameters contained in pumpkin fruits, namely: an increase in dry matter content leads to a significant increase in the content of sugars ($r=0.98$), vitamin C ($r=0.84$) and a decrease in β -carotene ($r=-0.73$). The tasting score of dry products significantly increased with the increase in the content of sugars ($r=0.69$) and vitamin C ($r=0.78$) and decreased with the increase in the proportion of pulp in the fruit ($r=-0.76$).

The identified positive and negative correlations between them may be the result of their antioxidant and prooxidant effects. According to B. Kulczynski & A. Gramza-Michałowska (2019), a strong correlation was observed between the content of carotenoids and flavonols ($r=0.91$,

$p<0.001$). That is, with an increase in carotenoid content, the flavonol content increases significantly, which can be used to predict the flavonol content in these studies. The studies of S. Chikpah *et al.* (2022) found that antioxidant activity has a direct positive correlation with β -carotene ($r=0.752$), total phenols ($r=0.903$), flavonoids ($r=0.917$), and ascorbic acid ($r=0.441$). Using the results of our correlation calculations and the data of other researchers, it can be argued that dried pumpkin products containing a high amount of carotenes and ascorbic acid will be characterised by high antioxidant properties and can be recommended as raw materials for the production of functional foods.

CONCLUSIONS

Pumpkin fruits of nutmeg varieties formed heavier fruits (6.2-7.4 kg), containing less bark (12.0-16.5%) and more pulp (71.2-78.0%), compared to large-fruited ones. The content of pulp used directly for drying among large-fruited pumpkins was 71.4 and 73.6%, respectively, and among nutmeg pumpkins – 78 and 74.1%, respectively, and muscovy pumpkins – Yanina and Gilea (control).

The content of the main biochemical parameters in fresh pumpkin fruits differed significantly and depended more on the species than on the variety. The fruits of large-fruited varieties accumulated a greater amount of dry matter (13.4-14.5%), dry soluble matter (11.3-12.3%), sugars (7.4-8.0%) and vitamin C (12.5-17.4 mg%). According to the content of β -carotene, which is the main biologically valuable component in fresh fruits and dried pumpkin products, large-fruited varieties prevailed over large-fruited ones and accumulated it in the range of 12.4-15.8 mg/100 g.

The fruits of the Gilea and Divo varieties contained the highest amount of this element – 15.8 ± 1.2 and 14.2 ± 0.4 mg/100 g, respectively.

To obtain 1 kg of dried products, 6.5–11.8 kg of fresh, unpeeled fruit or 4.9–9.1% of peeled fruit was required. More dried products could be obtained from large-fruited pumpkin varieties – 16.1–20.3%. According to the technological indicators that determine the profitability of drying, the large-fruited pumpkin variety Slavuta stood out: the yield of finished products was 20.3%, which is 2.5% more than in the control, and for the production of 1 kg of dried products, 6.5 kg of unpeeled fruits of this variety or 4.9 kg of peeled fruits were required.

Dried pumpkin products are a concentrate of dry matter, a biologically valuable food product, as it contains 87.4 to 91% dry matter, 34.5–50.3% sugars (total), 20.2–41.4 mg/100 β -carotene and 10.8–28.6 mg% vitamin C. For the production of functional foods, the most suitable are the fruits

of the nutmeg varieties Divo and Gilea, whose dry products contain 41.4 and 40.8 mg/100 g of β -carotene, respectively, and the large-fruited Slavuta and Polevichka, whose vitamin C content is 28.6 and 27.5 mg%.

Promising areas for further research could be the creation of food products (bakery, confectionery, pasta, etc.) with increased biological value with the addition of dried pumpkin products in various doses to the recipe. The study may also include the suitability of fresh pumpkin fruit for fermentation (pickling), as this method of processing will ensure maximum preservation of nutrients.

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CONFLICT OF INTEREST

None.

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Підбір плодів гарбуза різних видів та сортів для виробництва функціональних харчових продуктів

Анотація. З кожним днем в Україні та світі зростає зацікавленість споживачів до здорового способу життя та функціональних харчових продуктів з підвищеною біологічною цінністю. Для виробництва таких продуктів харчування важливо підібрати сировину, що відповідає

комплексу вимог щодо якості. Плоди гарбуза мають високий вміст поживних елементів, вітамінів, незамінних амінокислот та мінералів, що значною мірою відповідають цим вимогам. Метою досліджень була комплексна оцінка плодів гарбуза восьми сортів різних видів: великоплідних (*Cucurbita maxima* Duch) та мускатних (*Cucurbita moschata* Duchex Poir), вирощених в умовах лісостепу України, для виділення найпридатніших для сушіння та виробництва функціональних продуктів харчування. Під час проведення досліджень використано метод експерименту, відповідно до схеми досліджень, лабораторний метод – для визначення біохімічних, біометричних та органолептичних показників якості, статистичний – для проведення дисперсійного та кореляційного аналізів досліджуваних показників. Встановлено, що при використанні для конвективного сушіння плодів гарбуза великоплідних сортів можна отримати 16,1-20,3 % сухої продукції з вмістом цукрів 48,6-51,6 %, а мускатних – 11-14 та 34,5-40,2 % відповідно. Для виробництва функціональних харчових продуктів з вмістом β -каротину 40-41 мг/100 г (у перерахунку на суху речовину) доцільно використовувати плоди мускатних сортів «Гілея» та «Диво», а вітаміну С на рівні 28 мг % – великоплідних сортів «Славута» і «Польовичка». Виявлено, що зі збільшенням маси плодів суттєво зменшується вміст у них сухої речовини ($r=-0,68$), цукрів ($r=-0,67$) та вихід готової продукції ($r=-0,74$). Встановлено суттєвий прямий зв'язок між вмістом сухої речовини й цукрів ($r=0,98$), а також вмістом сухої речовини й виходом готової продукції ($r=0,94$). Матеріали статті становлять практичну цінність для селекціонерів, овочівників, спеціалістів переробних підприємств при виборі виду та сорту гарбуза для виробництва функціональних продуктів харчування

Ключові слова: якість; вітамін С; каротин; переробка; сушіння; сировина