Agronomy Research **19**(3), 1675–1690, 2021
https://doi.org/10.15159/AR.21.117

Suitability of various onion (*allium cepa*) varieties for drying and long-term storage

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Received: April 15th, 2021; Accepted: July 21st, 2021; Published: July 22nd, 2021

Abstract. In the paper, the results are presented obtained in the research into the fresh bulbs and the dried products of 9 onion varieties cultivated in the conditions of the Ukrainian Forest Steppe area with regard to their economical biology, biochemical, marketability and organoleptic indices. The varieties that are most suitable for convection drying and long-term storage have been identified. It has been established that the marketability of both the fresh bulbs and dried products depends on the masses of the bulbs. The Bronze d'Amposta and Harmony varieties deliver the greatest amount of marketable output (94.0 and 93.2%) featuring marketable bulbs with masses of 67.4 g and 70.4 g, respectively (r = 0.82). As the bulb mass increases, the amount of non-standard (r = -0.81) and small (r = -0.76) particles in the dried product decreases substantially. It has been found that the content of solid matter and sugars in fresh bulbs has effect on the yield and quality of the dried and reconstituted products. The Harmony and Skvirskaya varieties, the bulbs of which during the vegetation season build up 12.9% and 13.8% of solid matter, respectively, are distinguished by the highest dry product yield - 17.1 and 16.8%, respectively. Correlation has been established between the contents of solid matter and sugars in fresh bulbs (r = + 0.58). During the tasting of reconstituted onion products, the highest scores were awarded to the samples produced from the Skvirskaya and Harmony varieties - 7.0 points each on the 9-point scale, as their bulbs had accumulated over 7.0% of sugars (total). Judging by the aggregate of the researched indices, the Harmony and Skvirskaya varieties of onions are the most suitable for convection drying. It has been established that the preservation of onions in the conditions of stationary buried storage without artificial cooling depends on the duration of storage and the specific varietal features. Within the five months of the test storage, the preservation of bulbs of all the varieties was high and varied within the range of 80–93%. Longer storage is expedient only in case of the Harmony, Skvirskaya and Gospodinya, for which the bulb preservation rates for a seven month storage period has been shown to be equal to 90.2, 88.4 and 87.2%, respectively. It has been proved that the quantity of healthy bulbs depends to a significant extent on the solid matter content in the bulbs (r = 0.93).

Key words: bulb, drying, marketability, onion, quality, solid matter, storage, variety.

INTRODUCTION

Onions are a high yield and highly profitable vegetable crop, a widely used and valuable article of food that is consumed fresh, long-term stored and processed (Sych et al., 2010; Bobos & Zavadska, 2016). Onion bulbs are a source of biologically valuable agents, mineral salts and minor nutrient elements (calcium, potassium, magnesium, phosphorus and iron) that are indispensable for the human body (Block, 1985; Griffiths et al., 2002). The phytoncides concentrated in large quantities in the basal plate possess antibacterial, antifungal and other therapeutic properties. For that reason, onions have been used in medicine since the times of Hippocrates and their curative properties are acknowledged throughout the world (Sych et al., 2010). They are applied as a helminthicide, a remedy against scorbute, for strengthening the immunity and protecting from oncological diseases (Challier et al., 1998; Griffiths et al., 2002).

The content of main biochemical components in the bulbs varies depending on the variety, type of soil, applied fertilisers and weather conditions (Bolotskihh, 2001; Forney et al., 2010). Overall, fresh bulbs contain 12–16% of solid matter, 6–10% of sugars (fructose, saccharose, maltose, inulin), 1.6–2.5% of proteins, 0.8–1.3% of fibres (Block, 1985; Zavadska & Hrabovenko, 2016). Bulbs have greater nutritional value comparing with green leaves (Sych et al., 2010). Pungent varieties generally contain more solid matter, sugars and essential oils than sweet ones (Skaletska et al., 2014a). Because of that, they are more suitable for long-term storage and processing.

The issues of storage and processing have always been and will remain topical for any commodity producer of onions. Indeed, the production of this crop follows a seasonal pattern, the main harvesting output is obtained in the summer-autumn period and it is not fully consumed by the population. The almost whole harvested crop has to be stored for a certain period of time or processed. Due to the absence of dedicated stationary storage facilities and the inability to process the required amounts of raw stock, each year about 25–30% of the harvested crop is lost (Davydenko et al., 2020; Zavadska et al., 2020).

Storing vegetables is a multifaceted problem contingent on many factors. The onions' storage potential depends mostly on the variety, the climatic conditions during the vegetation, the dosing and timing of fertilizer treatment, watering, growth-regulating chemical dressing, the time of harvesting and the storage conditions (Suojala, 2001; Adamicki, 2005; Forney et al., 2010; Petropoulos et al., 2017; Irkov et al., 2018). The term of onion storage is contingent on the state of true dormancy. The ability of bulbs to remain in the state of dormancy has developed in the process of their evolution as the adaptation to adverse environment conditions (Ilić et al., 2009; Downes et al., 2010). The duration of this period is the characteristic feature of a specific variety – it is longer for late varieties and shorter for early ones (Sych et al., 2010; Bobos & Zavadska, 2016). On the one hand, the bulb dormancy duration depends on the amount of stored nutrients in the bulb, therefore, the greater their reserve is, the longer the period of storage can be, but that is not always the case (Skaletska et al., 2014a).

The germination of bulbs is prevented, first of all, by the application of cold. In case of onions, a temperature of 0 ± 1 °C significantly extends the period of dormancy (Ilić et al., 2009; Petropoulos et al., 2017). Higher temperatures in the storage promote a rise in the respiration intensity of the bulbs and the increased loss of the mass and solid

matter. At lower storage temperatures (below minus 3 °C) the risk of freezing the bulbs with their subsequent rapid damage arises (Sych et al., 2010).

The relative air humidity in facilities for storing onions of any designated purpose may not exceed 70–75%. During their storage, bulbs are more sensitive to an increase in the relative air humidity in the storage facility, than to an increase in the temperature. When the outer scales are wetted, the bulb comes out of the state of dormancy, starts sprouting and is in danger of rapid damage by diseases and complete loss of quality (Ilić et al., 2009).

Among the existing various ways of processing harvested vegetable crops, drying is the most widely used and economically sound method (Khan et al., 2016; Asiah et al., 2017). Dried onion is a nutritional ingredient of great commercial value that is popular throughout the world and is an indispensable component in all vegetable dry mixes added to starters, garnishes, sauces etc. It imparts to the prepared meals characteristic smell and taste and also enriches them with biologically valuable agents (Abdou et al., 2018; Edith et al., 2018).

Onion bulbs as the subject of drying are marked by a high water content, while the solid matter content in them is relatively low (Skaletska et al., 2014a). The bulk of the water is present in the free movable state and only about 5% of it is combined with cell colloids and reliably retained (Pavlović et al., 2011). That makes relatively easy to lightly dry the raw stock to a moisture content of 12–14% and complicates the removal of the remaining moisture (Dev et al., 2006; Arslan & Özcan, 2010; Asiah et al., 2017; Abdou et al., 2018; Bulgakov et al., 2020).

The quality of dried onion depends to a significant extent on the method of drying and the quality of feed stock, first of all, the varietal features and biochemical agents content (Dev et al., 2006; Abdou et al., 2018; Seifu et al., 2018). In the assessment of any fresh vegetable stock with respect to its suitability for drying, it is important to take into account the contents of solid matter, biologically valuable agents and sugars, as they have effect on the yield and quality of the dried product (Mota et al., 2010; Zavadska, 2020). In order to achieve high quality in the mechanical processing of bulbs, the following properties are essential: shape of the bulb, firmness, integrity of the skin and the strength of its bond with the fruit body. The thinner and tenderer the covering layer is, the easier the bulb is peeled. The presence of greened bulbs is not allowed, because in that case the dried product will have an atypical greenish colour (Zavadska & Hrabovenko, 2016). All the above-mentioned properties depend to a significant extent on the varietal features.

Thus, in accordance with the results of the research carried out in different countries, the suitability of onions for long-term storage and the possibility to obtain high quality dried products depends to a considerable extent on the varietal features. Every year, new varieties of onions come to the market, but their suitability for storage and processing is not fully investigated. The issue of storing onion bulbs in buried stationary storage facilities without artificial refrigeration, where the temperature conditions can vary has not been researched to a sufficient extent. The results obtained in the research can be used by scientists and manufacturers engaged in the cultivation, storage and processing of Allium cepa (Breu, 1996).

The aim of the paper was to investigate the marketability, biometric, biochemical, organoleptic and production indices of the quality of fresh bulbs and dried products of

various Allium cepa varieties in order to identify those that are most suitable for long-term storage and convection drying.

MATERIALS AND METHODS

The research was carried out in the period of 2012–2016 in the National University of Life and Environmental Sciences of Ukraine (NULES) following the single-factor experiment technique (Bondarenko & Yakovenko, 2001). Onions of the varieties under investigation were grown in the experimental collection field of the NULES without watering.

The total area of the recorded plots was equal to 144 m^2, one plot - 6 m^2. The research was carried out with three replicates. The seeds were sown following the 20 +50 cm pattern, the density was arranged to be at 600,000 plants per hectare. All the varieties including the reference one were sown simultaneously in the first ten-day period of April (05.04.2017, 07.04.2018, 06.04.2019). In the crop rotation system, onions were cultivated after cucumbers.

The location of the experimental plot was in the Forest Steppe zone. The climate of the zone was moderately continental, with warm summer and not cold winter. The soil in the plot was dark gray, medium podzolized, light loam. The thickness of the humus horizon was equal to 24–28 cm. The experimental plot featured a low humus content - 1.5–2.2%, a medium hydrolyzable nitrogen content - 26–38 mg kg^{-1}, the labile phosphorus content was equal to 43–61 mg kg^{-1} and potassium content was equal to 28–34 mg kg^{-1} (Bobos et al., 2019; Zavadska, 2020). Overall, the soil and climate conditions in the experimental vegetable field were favourable for cultivating bulbous vegetable crops.

According to the results of the analysis of the weather conditions during the growth seasons in the years of research (2017–2019), there was extremely great diversity in the moisture supply and temperature distribution within the vegetation periods. Rain spell were followed by prolonged droughts, which sometimes resulted in the marked decline in the moisture content of the soil and that, in its turn, affected the quality of the bulbs. The vegetation periods of 2017 and 2019 were dominated by rainless weather. The monthly average air temperatures were 1.5–2.0 °C higher than the respective long-term ones, while the amount of precipitation from April to September was lower than the long-term norm by 240–300 mm. The most favourable weather for plants occurred during their vegetation in 2019.

Figure 1. Bulbs of Skvirskaya reference variety. Ukrainian breeding, mid-season, semi-pungent, multi-purpose variety, vegetation period of 100–110 days, average bulb mass of 50–94 g.

After the completion of prospecting experiments, nine varieties and hybrids of onions suitable for cultivation in the Forest Steppe region were included in the programme of research. The thoroughly researched and widely cultivated Skvirskaya variety (Fig. 1) was chosen as the reference variety. The programme of research is presented in Table 1.

Apart from the traditional onion cultivars of white and yellow colours, it was decided to include in the research design also the Bronze d'Amposta variety of Dutch origin with reddish-bronze coloured bulbs (Fig. 2).

After harvesting the ripe onions, one most characteristic replication of each variety was subjected to the comprehensive analysis of unmarketable bulbs. These were classified into fractions and separately weighed, then the percentage of the total mass of the harvest was calculated and the marketability was determined.

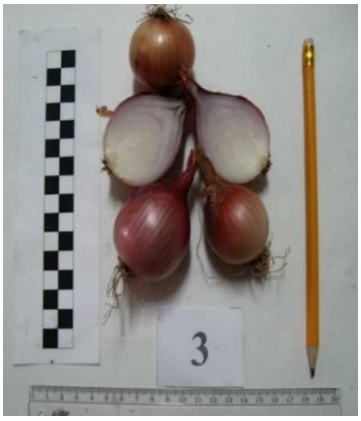

Figure 2. Bulbs of Bronze d'Amposta Dutch-origin variety (Antaria Ltd). Mid-season, multi-purpose variety, average bulb mass - 140–150 g, diameter - 8–10 cm, potential yield - over 60 t ha^{-1}.

Fresh bulbs were appraised by the set of biometric indices. The average mass of the marketable bulb was determined using the average sample with a mass of 10 kg taken from all replications. The number of bulbs in the sample was counted and the average mass was calculated to an accuracy of 1 g. The bulbs typical for the variety under consideration were used to measure the diameter in the largest cross-section as well as their length. The bulb's shape index was determined as the ratio of its length to its diameter. The biometric indices of bulbs were appraised by the measure of stability, using for that purpose the Lewis's stability factor [S.F. = Xmax·$(Xmin)^{-1}$]. Its value varies from 1.0 up. The closer the factor is to 1.0, the more stable the index under investigation is.

4 kg of bulbs of each variety were sampled for drying with three replicates. They were weighed, classified, washed by hand, peeled removing the dry scales and basal plate with rootlet remnants, then the amount of waste was determined. After peeling, the bulbs were again washed in running water, cut by hand into cubes dimensioned $1.0 \pm 0.2 \times 1.0 \pm 0.2$ cm. The cut product was uniformly distributed over the trays of the Sadochok 2-M drying cabinet at a rate of 2 kg m^{-2} and loaded into the process chamber of the drying cabinet (Fig. 3). The drying apparatus employed in the experiments was a chamber-type dryer operating on the batch loading principle. Prior to loading a batch, the drying chamber was heated in advance to a temperature of 50 °C. All the trays were loaded into the dryer simultaneously. In order to ensure uniform drying-up, the raw stock was stirred several times in the course of drying.

The shredded product was dried at a temperature of 60 °C until its moisture content reached 10–12%. The earlier research has proved that such a temperature is optimal for drying onion, it ensures the preservation of the organoleptic properties and biologically valuable agents (Seifu et al., 2018).

After the drying was complete, the product was cooled down, samples were taken for biochemical and technological analysis and packed in airtight polythene bags. The dried product was stored in darkness at a temperature of 12–16 °C and a relative air humidity of 65–70%.

Figure 3. General appearance of chamber-type convection dryer with onion test samples in the process of drying. Power supply of drier: 220 V, 50 Hz, power rating - 1,250 W. Fresh onion batch load is 18 kg, at one tray load of 2 kg. Maximum temperature in process chamber - 65 ± 5 °C. Control of drying conditions is semi-automatic.

The research into the suitability of onion bulbs for long-term storage was carried out in the period of 2017–2019. Standard bulbs were used in the experiments. They were placed in capron mesh bags in order to make 5 kg samples with 4 replications. The bulbs were stored in a stationary buried storage facility at a temperature of 0…+2 °C within the main interval (October to February), the relative air humidity was maintained at a level of 70–75%. Checking was carried out in 2.5 months and at the end of storage (in 7 months).

The biochemical, organoleptic and laboratory testing and analysis of the fresh bulbs and dried products was carried out at the facilities of the research-and-study laboratory under the Department of Storage, Processing and Standardization of Crop Products, NUBiP, in accordance with the standard practices (Skaletska et al., 2014a, 2014b).

For the purpose of determining the biochemical indices, for each variety an average sample of shredded product with a mass of 2 kg was taken, 100 g of fresh product were sampled with 3 replicates and then immediately the required tests were performed. The solid matter content was determined in accordance with DSTU ISO 751 with the use of thermal gravimetric analysis by drying the sample in the drying cabinet at a temperature of 100–105 °C until the mass became constant. 30 g of shredded fresh bulbs were picked from the prepared laboratory sample and placed into the previously dried, weighed and enumerated weighing cups, then weighed to an accuracy of 0.01 g. After that, the weighing cups were opened, placed into the drying cabinet and dried, first, at a temperature of 50–60 °C (4–5 h), then 4–6 h at 100–105 °C. After the drying, the weighing cups were closed with caps, cooled down in the exsiccator and weighed. Then they were opened again and the drying continued for another 1.5–2.0 h, after which the weighing was repeated. The procedure was repeated until a constant mass was reached (the difference between two consequent weighing results did not exceed 0.02 g).

The soluble solid matter content was determined with the use of a refractometer in accordance with the provisions of DSTU ISO 2173. 10–20 g of shredded mass were picked from the laboratory sample, 1–2 cm^3 of onion juice were filtered from the mass, then 2–3 drops of the juice were placed on the prism of the refractometer. 4–5 readings

were taken, then the mean refractive index was calculated with a correction for the temperature. The Bertrand's method was used for determining the content of sugars (total), while the content of vitamin C was determined with the use of 2,6–dichlorophenolindophenol solution (of blue colour) reduced to the colourless compound by extracts from plants containing ascorbic acid (Skaletska et al., 2014b).

The tasting assessment of the dry and reconstituted products of onions was carried out by the panel of at least 7 experts using the 9-point scale. Part of the combined sample of the dry product was placed on a white piece of paper, then the appearance, shape of particles and product colour were determined under diffused bright daylight illumination. In the assessment of the colour, its density, uniformity and correspondence to the initial stock colour were taken into account. When determining the body, the elasticity, firmness, fragility and flowability were taken note of. In the evaluation of the flavour and taste, their purity and intensity are assessed as well as the absence of extraneous odours and tastes.

The dried onion was determined as follows: a batch weighing 2.5 g was placed into a 100 mL beaker and poured over with 50 mL of distilled water (with a temperature of 20 °C). The batch had swollen for one hour. 50 mL of distilled water with the same temperature were filtered through a funnel with a paper filter, in 20 and 40 minutes after that, the funnel with the damp filter was weighed.

In one hour, the content of the beaker was filtered through the weighed funnel with the filter, it had been left for 30 minutes to drain the water, then the funnel with the swollen batch was weighed. The weight of the swollen batch was determined as the difference between the weights of the funnel with the filter and the batch. The swelling grade was calculated as the ratio between the mass of the dried batch taken for analysis (2.5 g) and the mass of the swollen batch after 60 min of soaking.

The research results were processed with the use of mathematical methods, the least significant difference (LSD), the correlation and regression relations were determined following the standard practices.

The biometrical indices of the bulbs were estimated by their stability factor with the use of the Lewis stability factor ($S.F. = X_{max}/X_{min}$). The latter's value varies from 1.0 and higher: the closer the factor is to 1.0, the more stable the index under investigation is.

The mathematical analysis of the data was carried out following the standard methods of the variance analysis (Bondarenko & Yakovenko, 2001) with the use of the Agrostat computer programme for the statistical analysis of data. The correlation between the quality indices under research and the regression coefficients were calculated with the use of the Microsoft Excel programme.

RESULTS AND DISCUSSION

The onion varieties under investigation significantly differed as regards their biometrical and commodity indices (Table 1).

The bulb masses varied within the range of 54.20–70.45 g. The heaviest bulbs were produced by the Harmony variety - 70.4 g, which was by 3.6 g greater than in case of the reference cultivar, the lightest ones were produced by Gospodinya (54.5 g) and Mavka (54.2 g). The earlier research has proved that the uniformity of the bulbs with regard to their masses has an effect on the amount of waste generated during their mechanical cleaning. Another known fact is that bulbs with more equal masses are better

preserved in storage. As is seen from the research results, the Bronze d'Amposta and Skvirskaya (reference) varieties have the most uniform bulbs with regard to their masses. The Lewis stability factor (S.F.) of these cultivars is the closest to 1.0.

Table 1. Biometrical indices and marketability of bulbs for different varieties, average for 2012–2014

Name of variety, hybrid	Mass of commodity bulb		Diameter	Shape	Marketability
	g	S.F.	(mm)	index	(%)
Skvirskaya (reference)	66.8	1.08	53 ± 2	0.9	93.4
Arenal F_1	63.6	1.16	50 ± 3	1.1	89.3
Bronze d'Amposta	67.4	1.04	55 ± 2	1.0	94.5
Buran	58.6	1.17	48 ± 4	1.0	90.4
Harmony	70.4	1.10	53 ± 2	1.3	95.2
Gospodinya	54.5	1.22	45 ± 3	1.1	88.4
Grandina	65.4	1.11	53 ± 3	1.1	92.0
Mavka	54.2	1.20	48 ± 4	1.2	89.5
Sherpa F_1	56.7	1.28	44 ± 4	0.9	87.4
LSD	3.4				2.8

The diameter of the bulbs is another important standardized quality index. In accordance with the effective standard, the first commercial grade accepts bulbs with a diameter of at least 50 mm. The bulbs of the Skvirskaya (reference), Bronze d'Amposta, Harmony, Grandina varieties and the hybrids Arenal F_1, Sherpa F_1 met the requirements of the effective standard with respect to this index and, therefore, were classified as the first commercial grade bulbs in accordance with the results of the marketability appraisal.

The next index represents the shape of the bulbs. Among the examined varieties, the Harmony cultivar had the longest bulbs, their shape index was equal to 1.3. The bulbs of the Skvirskaya (reference) and Sherpa varieties had a flattened and rounded shape (shape index - 0.9).

The marketability of the bulbs in the variety range under investigation was rather high varying within the range of 87.4–95.2%. The greatest shares of commodity specimen were delivered by the Harmony and Bronze d'Amposta varieties - 95.2 and 94.5%, respectively. The lowest commodity ratio was obtained for the bulbs of the Sherpa F_1 hybrid - 87.4%, which was 6% lower as compared to the reference variety. The correlation analysis carried out by the authors resulted in establishing the essential direct relation between the mass of the bulb and its marketability - $r = 0.82 \pm 0.6$. The regression analysis showed that an increase of 1 g in the mass of the bulb improved their commodity ratio by 0.77%.

As has been proved by the data in the literature and the authors' own research, the contents of the main biochemical components, especially solid matter and sugars, are the most important factors that determine the output and quality of dried product. Among the researched varieties, the greatest amount of solid matter was accumulated in the bulbs of the Harmony and Skvirskaya (reference) varieties - 12.9% and 13.8%, respectively, the lowest - in the bulbs of the Bronze d'Amposta variety - 9.5% (by 4.3% (substantial difference) lower than in the reference case). In all other cases under consideration no significant difference was found with regard to this index (Table 2).

Table 2. Contents of main biochemical components in fresh bulbs of different onion varieties, average for 2012–2014

Name of variety, hybrid	Content in bulbs (%)			Vitamin C
	Solid matter	Acids	Sugars, total	(mg %)
Skvirskaya (reference)	13.8 ± 1.2	0.32 ± 0.04	7.8 ± 0.4	6.2 ± 1.0
Arenal F_1	11.6 ± 0.9	0.42 ± 0.05	6.3 ± 0.3	4.0 ± 0.4
Bronze d'Amposta	9.5 ± 0.4	0.46 ± 0.04	6.4 ± 0.3	4.5 ± 0.8
Buran	11.4 ± 0.7	0.34 ± 0.03	7.3 ± 0.4	4.4 ± 0.7
Harmony	12.9 ± 1.1	0.35 ± 0.02	7.3 ± 0.3	6.5 ± 0.6
Gospodinya	12.3 ± 0.8	0.37 ± 0.04	6.2 ± 0.2	5.7 ± 1.1
Grandina	12.1 ± 1.0	0.38 ± 0.03	7.3 ± 0.3	5.1 ± 0.6
Mavka	11.4 ± 0.7	0.45 ± 0.05	5.3 ± 0.2	4.7 ± 0.5
Sherpa F_1	10.7 ± 0.8	0.23 ± 0.02	5.7 ± 0.3	3.3 ± 0.6

The greatest amounts of sugars (total) were found in the bulbs of the Skvirskaya (reference), Harmony and Buran varieties - 7.8 and equally 7.3% each, respectively. It has been established that there is an average direct correlation between the solid matter content and the sugar content in the bulbs - $r = + 0.58 \pm 0.02$.

The highest contents of titratable acids were found in the bulbs of the Bronze d'Amposta and Mavka varieties - 0.46 and 0.4%, respectively, the lowest - in the bulbs of the Sherpa F_1 hybrid - 0.23%. The bulbs of other varieties did not show any significant difference in this component. The greatest amounts of vitamin C were contained in the fresh bulbs of the Skvirskaya (reference) and Harmony varieties - over 6 mg %.

The quantity of waste generated in the process of mechanically cleaning the bulbs and preparing them for drying depended on the variety (Fig. 4). The smallest amount of waste was generated in the process of preparing the raw material for drying by the bulbs of the Bronze d'Amposta variety - 11.2%, which was 1.2% less than in case of the reference variety (non-significant difference). Little waste was generated also by the bulbs of the Harmony variety -11.7%, which was 0.7% less than in case of the reference variety.

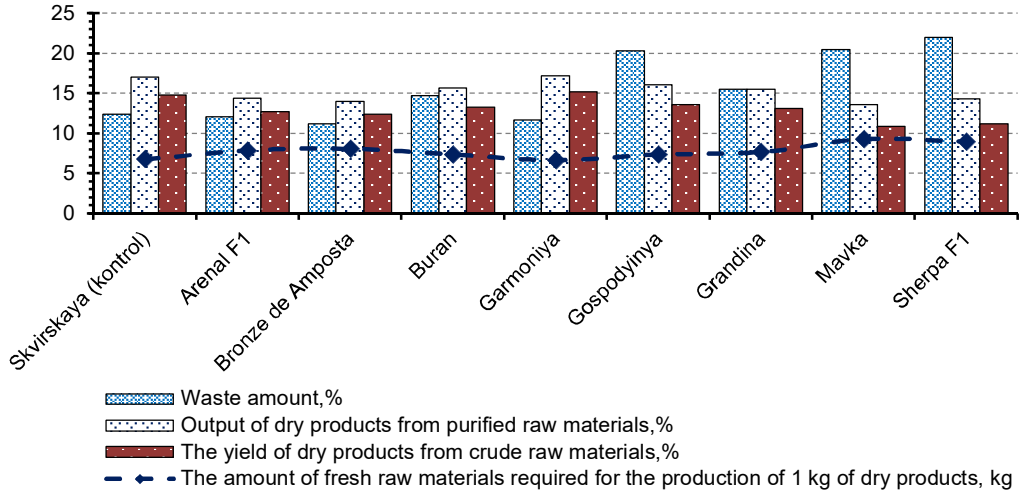

Figure 4. Amount of waste and yield of dried products for different varieties of onions, average for 2012–2014.

As regards the yield of finished commodity from cleaned raw material, the Harmony and Skvirskaya (reference) varieties stood out - 17.2 and 17.0%, respectively. The research results proved that the solid matter content in the initial stock and the generated waste amount had the greatest effect on this index. In view of that, the smallest amount of the fresh product was needed to obtain 1 kg of the dried product in case of the bulbs of the Harmony and Skvirskaya (reference) varieties - 6.7 and 6.8 kg, respectively.

For the consumers of dried products, the important factors are the content of biochemical components, the biological and nutritional value as well as the organoleptic indicators (Fig. 5).

The greatest solid matter content was found in the dried product made from the bulbs of the Sherpa F_1 hybrid, - in excess of 90 %. The highest sugar content was in the dried products of the Harmony and Bronze d'Amposta varieties - 41.4 and 40.5%, respectively, which was 2.7 and 2.1% more than in case of the reference variety.

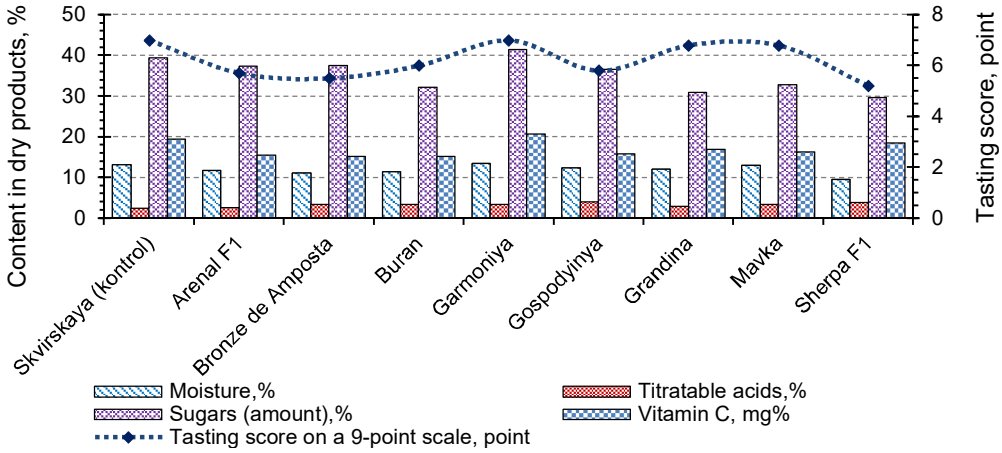

Figure 5. Tasting score and content of main biochemical elements in dried products of different varieties of onions, average for 2012–2014.

As was obvious from the obtained data, the moisture content depended on the sugar content. The correlation analysis carried out by the authors resulted in establishing the direct relation between the two indices - $r = + 0.62 \pm 0.12$.

The dried products contained considerable amounts of vitamin C - 15.1 to 20.7 mg %. The dried product of the Harmony variety exhibited a high biological value - 20.7 mg % of vitamin C, which was 1.4 mg % more than in case of the reference variety. Also, almost all the mineral salts and minor nutrient elements were preserved in the drying process (Sasongko et al., 2020).

As a result of tasting the reconstituted product, the highest scores were awarded to the samples produced from onions of the Skvirskaya (reference) and Harmony varieties - 7.0 points each on the 9-point scale, the lowest - the Sherpa F_1 hybrid (5.2 points). In the reconstituted product of the Sherpa hybrid, the particles had a soft texture and a relatively dark colour (Fig. 6). Sufficiently high scores were awarded to the dried and reconstituted products of the Mavka and Grandina varieties - 6.8 points.

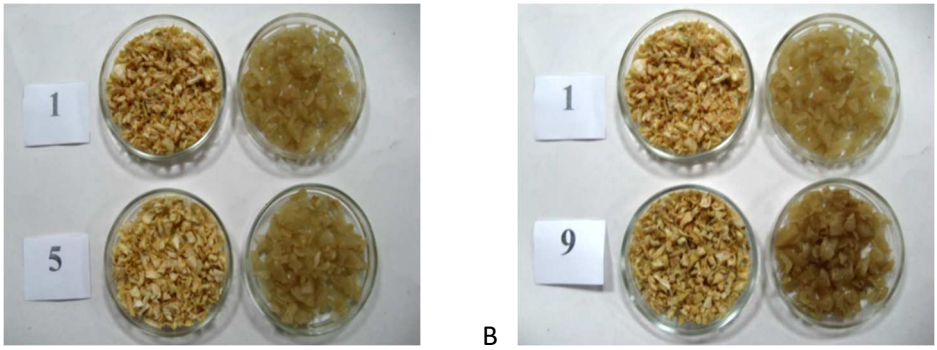

Figure 6. Samples of dried and reconstituted onion products, 2013 harvest.

A: 1 – Skvirskaya (reference); 9 – Sherpa F_1 hybrid; tasting score awarded to samples of reconstituted Sherpa hybrid product- 5.2 points on 9-point scale because of dark colour and soft texture of particles. B: 1 – Skvirskaya (reference); 5 – Harmony variety; tasting score awarded to samples of these varieties - 7.0 points on 9-point scale. Dried and reconstituted particles had minimum change of colour as compared to initial stock, elastic texture, distinctive intense flavour.

A rather low score was awarded by the tasting panel to the samples of reconstituted product of the Bronze d'Amposta variety - 5.5 points on the 9-point scale, which was 1.5 points lower as compared to the reference variety (Fig. 7). It ought to be noted that the dried product of this variety achieved a rather high score in the tasting procedure (6.4 on the 9-point scale), met the requirements of the effective standard, had an elastic texture, distinctive flavour and taste.

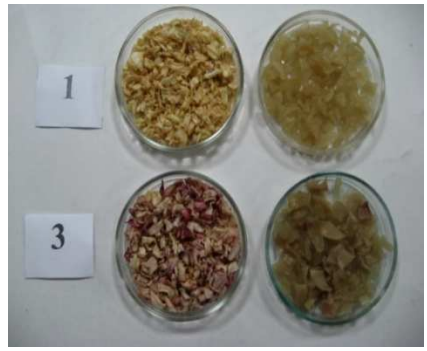

Figure 7. Samples of dried and reconstituted products of Skvirskaya (reference) (1) and Bronze d'Amposta (3) varieties, 2013 harvest: tasting score of dried product samples of Bronze d'Amposta variety - 6.8 points on 9-point scale, reconstituted product - 5.5 points. Reconstituted product had non-uniform darkish colour, soft texture.

Dried onion contains a considerably greater amount of nutritious and biologically valuable components in comparison to the initial stock (Fig. 8).

For example, in the researched raw material the content of vitamin C varied within the range of 3.3–6.5 mg %, while in the dried products - 15.1–20.7 mg % (three-fold rise). However, after reassessment, it had been established that considerable loss of vitamin C took place during the preparation of the raw material to drying and in the process of drying itself. The extent of this loss depended on the varietal features. The lowest loss of ascorbic acid happened in the products of the Mavka, Gospodinya and Grandina varieties - within the range of 45–50% of the initial content in the raw material. Higher loss of vitamin C content, comparing to the reference variety, took place in the process of drying the raw material of the Harmony variety (4.5% more) and the greatest loss rate was in case of the Sherpa F_1 hybrid (13.4% more). In the latter case, the loss of ascorbic acid exceeded 60%.

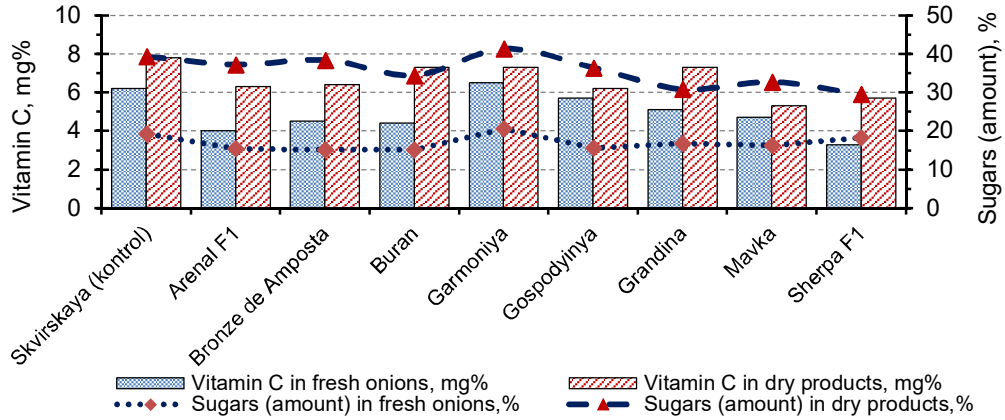

Figure 8. Contents of vitamin C (mg %) and sugars (total, %) in fresh bulbs and dried products of different varieties of onions, average for 2012–2014.

A similar concentration in dried onion was observed for sugars - their content varied within the range of 30–40%, while in the initial stock the figures where 5.3–7.8%. However, unlike vitamin C, the content of sugars in some cases even increased during the drying process in comparison to the initial stock. For example, in the dried product of the Bronze d'Amposta variety their content increased by 1.2% as compared to the initial stock. Obviously, in the process of drying, transformation of polysaccharides into monosaccharides and disaccharides took place and that resulted in the increase of the total sugars.

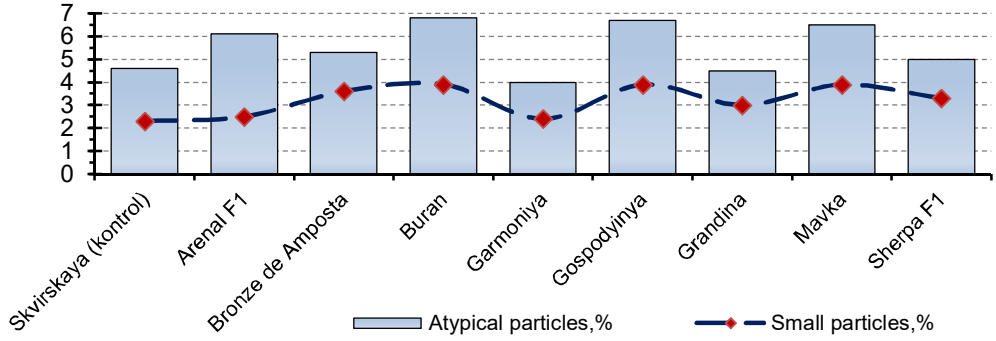

Figure 9. Contents of atypical and small particles (%) in dried products of different varieties of onions, average for 2012–2014.

When assessing the quality of any product, another issue of importance is its compliance with the specifications of the effective standard, in particular, the presence of atypical and small particles (Fig. 9). In the research, the atypical particles included those burned during the drying or having black spots and/or a colour unusual for the variety, also the remnants of dry scales and basal plates. Their content depended on the variety and varied within the range of 4.0 to 6.7%. The greatest amounts of such particles were registered in the dried product samples of the Gospodinya and Mavka varieties - 6.7 and 6.5%, respectively.

The results of investigations had proved that there was an essential inverse correlation between the commodity bulb mass and the amount of atypical (r = -0.81) and small (r = -0.76) particles in the finished commodity. That is, when the bulb mass grew, the amount of non-standard (atypical and small) particles in the dried product considerably decreased. Accordingly, the lowest quantities of such particles were present in the dried product samples of the varieties with greater commodity bulb masses - Harmony, Skvirskaya (reference), Grandina, Bronze d'Amposta.

Thus, by the results of the appraisal of dried onion products with respect to their commodity indices, the Harmony, Skvirskaya (reference) and Grandina varieties stood out with their samples containing 4.0–4.6% of atypical and 2.3–3.0% of small particles.

The scope of investigations included also the research into the suitability of bulbs of different onion varieties for long-term storage. The amount of healthy bulbs at different stages of storage to a significant extent depended on the varietal features and duration of storage (Fig. 10).

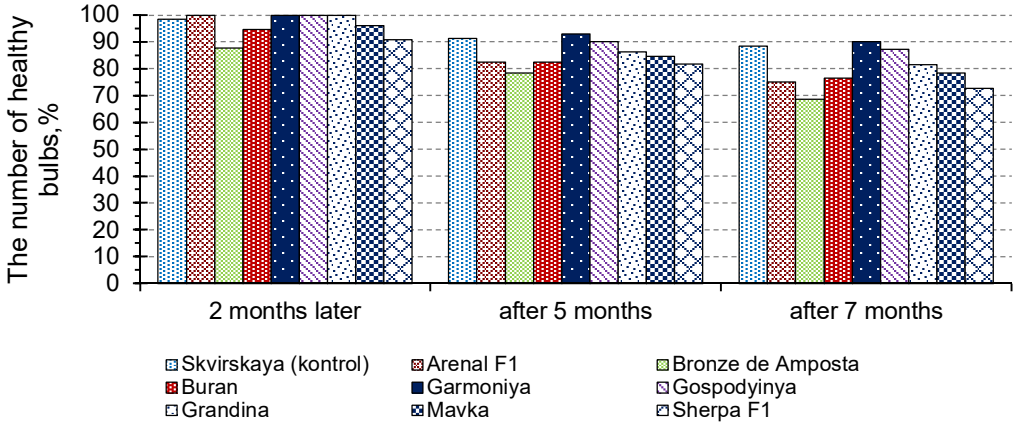

Figure 10. Amount of healthy onion bulbs during long-term storage in case of different varieties and hybrids, average for 2014–2016.

Throughout the first two months (until the end of October) of the storage in the conditions of a stationary buried storage facility without artificial cooling, the integrity of the bulbs of the Arenal F_1 hybrid and the Harmony, Gospodinya and Grandina varieties was 100%. The bulbs of the Bronze d'Amposta variety started germinating already at this stage (8.5% of sprouted bulbs). After five months of storage (by the end of January) the bulbs of the Sherpa F_1 hybrid had also started germinating - circa 18% of them were sprouted within this storage interval. The greatest amount of healthy bulbs after five months of storage (by the end of January) was registered in the samples of the Harmony and Skvirskaya (reference) varieties - 93.0 and 91.2%, respectively.

In seven months after the start of storage, the bulb integrity rates of the varieties under investigation varied within the range of 68.7 to 90.2%.

The highest suitability for long-term storage was shown by the bulbs of the Harmony, Skvirskaya (reference) and Gospodinya varieties - their integrity was at levels of 90.2, 88.4 and 87.2%, respectively. The most substantial losses were observed in the last month of the storage period (March), which can be explained by the temperature

fluctuations in the storage facility at that time. At the end of the storage period, the samples of the Bronze d'Amposta, Sherpa, Arenal varieties featured a significant share of sprouted, soft bulbs. In the absence of storage facilities with artificial cooling systems, it is advisable to complete the sale of onion bulbs within 5 months after their harvesting, thus ensuring their high marketability and minimum losses. It has been established that there is an essential correlation between the content of solid matter and the amount of healthy bulbs preserved in the process of storage (r = 0.93), which is supported by the data in the own studies and from other authors. The completed calculations on the regression relationship have proved that an increase of 1.0% in the solid matter content results in the amount of healthy bulbs improving by 0.83%.

CONCLUSIONS

As regards the aggregate of the quality indices determined for the fresh and dried onion products, the Harmony and Skvirskaya (reference) varieties are the most suitable ones for convection drying. The fresh bulbs and dried raw material of these varieties feature well-balanced contents of main biochemical components and high organoleptic indicators, deliver a great output of dried products (in excess of 17%). In order to produce 1 kg of dried products, it is necessary to input 6.7 kg of fresh raw material of the Harmony variety and 6.8 kg - of the Skvirskaya variety. The dried onion contain significant amounts of vitamin C - 15.1 to 20.7 mg %. The dried products of the Harmony variety have a high biological value - 20.7 mg % of vitamin C.

The bulbs of the Harmony, Skvirskaya and Gospodinya varieties are the most suitable for long-term storage in the conditions of a stationary buried storage facility without artificial cooling - the share of healthy bulbs after seven months of storage is 90.2, 88.4 and 87.2%, respectively. The share of healthy bulbs essentially depends on the solid matter content in them (r = 0.93). In the absence of storage facilities with artificial cooling systems, it is advisable to complete the sale of onion bulbs within 5 months after their harvesting, which will ensure their high marketability and the minimum loss of quality.

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