Slovak Journal of Food Sciences

Potravinarstvo Slovak Journal of Food Sciences
vol. 14, 2020, p. 1097-1104
https://doi.org/10.5219/1392
Received: 8 May 2020. Accepted: 2 August 2020.
Available online: 28 November 2020 at www.potravinarstvo.com

ISSN 1337-0960 (online)

THE QUALITATIVE PARAMETERS OF POTATO TUBERS IN DEPENDENCE ON VARIETY AND DURATION OF STORAGE

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ABSTRACT

The qualitative parameters of the potatoes tubers may be significantly changed depending on the variety, group of ripening, way, regime, and duration of storage. So, these researches aimed to define the influence of the variety characteristics and duration storage on qualitative parameters of tuber potatoes. Five potato varieties of two ripening groups were used for testing: medium-early (Satina, Red Lady, Mozart) and medium-ripe (Aroza, Sifra). The chemical properties such as dry matters (DM), starch, sugars (total and reducing), crude protein (CP), ascorbic acid (AA), and nitrates content were determined before and after 2, 4, and 6 months of storage. DM lost during the storage of potato tubers, especially during the period from 4 to 6 months. The group of ripening did not influence this index. Potato tubers of all varieties had high starch content and the duration of storage had a light effect on the level of its losses. In the medium-early group, maximum changes of starch were 1% but in the medium-ripe – 1.9%. A strong effect on the quantities of total sugars (TS) had varietal characteristics of the potato but a group of ripening had light influence. The highest content of sugars was Satin (0.65%) and the smallest Sifra (0.22%) and Mozart (0.23%). After 6 months of storage content of TS depending on the variety increased from 2 till 5 times, while the reducing sugars (RS) increased at least five times and at the end of storage were 0.4% to 0.65%. The amount of AA and its losses during storage depended on the variety. The relative losses during the total storage period were 21.9% in the medium-early group and 28.1% in the medium-ripe. Influence ripening group on level changing AA was not detected. Nitrates' content did not exceed the maximum permissible level (250 mg.kg^{-1}). Their quantities after 6 months were 47 – 61 mg.kg^{-1}.

Keywords: potato; variety; ripening group; storage; qualitative parameters.

INTRODUCTION

The biochemical composition of potato tubers is an indicator of its nutritional value and culinary properties **(Amber, Chegeni and Ferruzzi, 2018)**, which depends on variety, soil, climate, the technology of crop growing, duration and storage conditions **(Nourian, Ramaswamy and Kushalappa, 2003a; Nourian, Ramaswamy and Kushalappa, 2003b)**.

The valuable of potatoes as food is determined by the favorable biochemical composition, which is represented by DM, starch, sugars, CP, and AA. Other components that can affect its nutritional quality are present in smaller quantities in potatoes **(Amber, Chegeni and Ferruzzi, 2018)**.

The content of DM in potatoes can fluctuate within wide enough ranges of 15 – 32% and depends on both varietal characteristics and agro-climatic factors. Their quantities influence the energy value of potatoes and their culinary properties – taste, structure, consistency, and color of pulp after cooking. The quantities of DM decreasing due to physiological processes that take place in the potatoes tubers during the storage **(Zgórska and Grudzińska, 2012; Gunko and Yakovlev, 2016)**.

The basis of DM in potatoes (70 – 80%) presented by starch. Its quantity defines the nutritional value of potato tubers. The amount of starch depends primarily on variety, growing conditions, and has ranged from 9 to 24% by raw weight in the different varieties **(Liu, et al., 2007; Lu, et al., 2011; Ngobese, et al., 2017)**.

Late-ripening potato accumulates more starch substances. The storage process is accompanied by the constant transformation of starch to sugar and vice versa and as a result physiological processes that take place, their quantity was decreasing **(Mareček, et al., 2016)**.

The biological value of potatoes is determined by the content in the tubers of CP. Its biological value is superior compared to the protein of most crops because it contains all the irreplaceable amino acids that are not synthesized in humans and has an index of valuability is 60 – 92 **(Bártováa, et al., 2009)**.

On average, potatoes contain CP about is 1.9 – 2.2% by raw weight. In the processing of potatoes, protein value is not taken into account in our time, however, in the future, they will take into account the nutritional and physiological value and pass mainly to the processing of potatoes, which are rich in protein. The process of storage is accompanied by quantitative changes in the CP: initially, its amount increases and becomes maxima in March but further storage decreases its content **(Järvan and Edesi, 2009)**.

Freshly harvested potatoes are characterized by low content of sugar: an average about is 0.7% by raw weight or 2.8% by weight of DM. More than half of them are glucose (65%), about 30% – sacharose and only 5% fructose. In the outer and inner layers of tubers the TS content is almost the same, but in the outer layers is presented sacharose and in the central part – monosaccharides. The process of storage escorted constantly transforms starch-to-glucose and vice versa **(Amjad, et al., 2019)**.

As a result, potatoes germination in their tubers may accumulate a large quantity of phosphorus esters of sugar and when there is an intense decomposition of starch to form up to 1% maltose. Increasing the number of sugars (glucose) – is undesirable, as it affects the culinary properties of potatoes, especially the quality of fried products **(Camire, Kubow and Danielle, 2009; Amjad, et al., 2019)**.

Tubers of potatoes contain different vitamins: thiamine, riboflavin, pantothenic acid, pyridoxine, nicotinic acid, carotenoids, and AA but only vitamin C which has content in the ranges from 5 till 40 mg% by raw weight has biological value. Other vitamins presented in quantities very smaller than needed for the health of a person **(Love and Pavek, 2008)**.

The highest content of AA is presented in fresh harvest potato tubers. During storage, their content decreases, especially as a result of germination **(Külen, Stushnoff and Holm, 2013)**.

Potatoes of two groups of ripening – medium-early and medium-ripe were used in the investigations. The choice of potato varieties from these two groups explained by their prevalence in the area, the increase in active temperatures in June, July, and August, low rainfall in the current period and, the need for the stable provision of large cities in the summer and autumn **(De Temmerman, Hacour and Guns, 2002; Hijmans, 2003)**.

Early planting time contributes to large and stable potato harvests in the Forest-Steppe zone of Ukraine **(Voitsehivskyi, et al., 2019)**.

This work aimed to investigate the effect of storage duration, variety characteristics, and ripeness group on changes in the biochemical composition of potato tubers.

Scientific hypothesis

Potatoes are characterized by large quantities of varieties that differ from each other, both in terms of the growing season and biochemical composition. The quality of potatoes tubers changes during storage. The magnitude of these changes depends on the characteristics of soil, climatic conditions, cultivation technology, varietals' characteristics, the activity of physiological processes, conditions, and duration of storage.

MATERIAL AND METHODOLOGY

Material

Materials of the study were potatoes tubers 5 varieties companies HZPC (Netherlands) and Solana (Germany) which apply to two groups of ripeness: medium-early (Satina – control, Red Lady, Mozart) and medium-ripe (Aroza – control, Sifra) **(Figure 1)**. Potatoes were stored in a specialized fridge chamber which equipment by ventilation. Conditions of storage: temperature + 2 to +4 ºC, air humidity 90 – 95%, ventilation – three-volume of air during one day. A sample of 25 kg of potatoes tubers each cultivar was stored in these conditions. From this sample of 1.5 – 2 kg, tubers were taken for the determination of biochemical parameters.

Methodology

Potatoes were grown during 2016 – 2018 years in the conditions of LLC Biotech LTD (Kyiv region, Boryspil district, Horodyshche village), which is located in the Forest-Steppe zone of Ukraine. The total area size of the field for potatoes cultivation is 300 m^2, the accounting area is 240 m^2, the repeatability – 3 times. The potato was cultivated by a common methodology for this crop in the Forest-Steppe zone of Ukraine.

In potato tubers, before storage and after 2, 4, and 6 months were determined DM, starch, TS, RS, CP, AA, and nitrates. The following chemical analyses were performed:

1. Content of DM was performed by the weighted method **(Skaletska, Podpryatov and Zavadska, 2014; DSTU 7804, 2015)**;
2. Content of starch was performed polarimetrically by Ewers **(Savchuk, at al., 2005)**;
3. Content of AA – to restore the Tillmans reagent, by extraction acid solution of sample potato followed by filtration of the resulting substrate titrimetric method according to the state standard of Ukraine 7803 **(DSTU 7803, 2015)**;
4. Content of TS and RS was performed by photocolorimetric method on the photo calorimeter KFK-3-01 according to the state standard of Ukraine ISO 4954 **(DSTU ISO 4954, 2008)**;
5. Content of CP was performed according to the state standard of Ukraine 7169 **(DSTU 7169, 2010)**;
6. The content of nitrates was performed by potentiometry according to the state standard of Ukraine 4948 **(DSTU 4948, 2008)**.

Statistic analysis

All experiments were carried out in triplicate and standard deviations for replication were calculated. The results were statistically analyzed using analysis of variance (ANOVA). Measurements of duplicate samples were expressed as means ± standard deviation. The level of significance associated with the statistical test was 0.05.

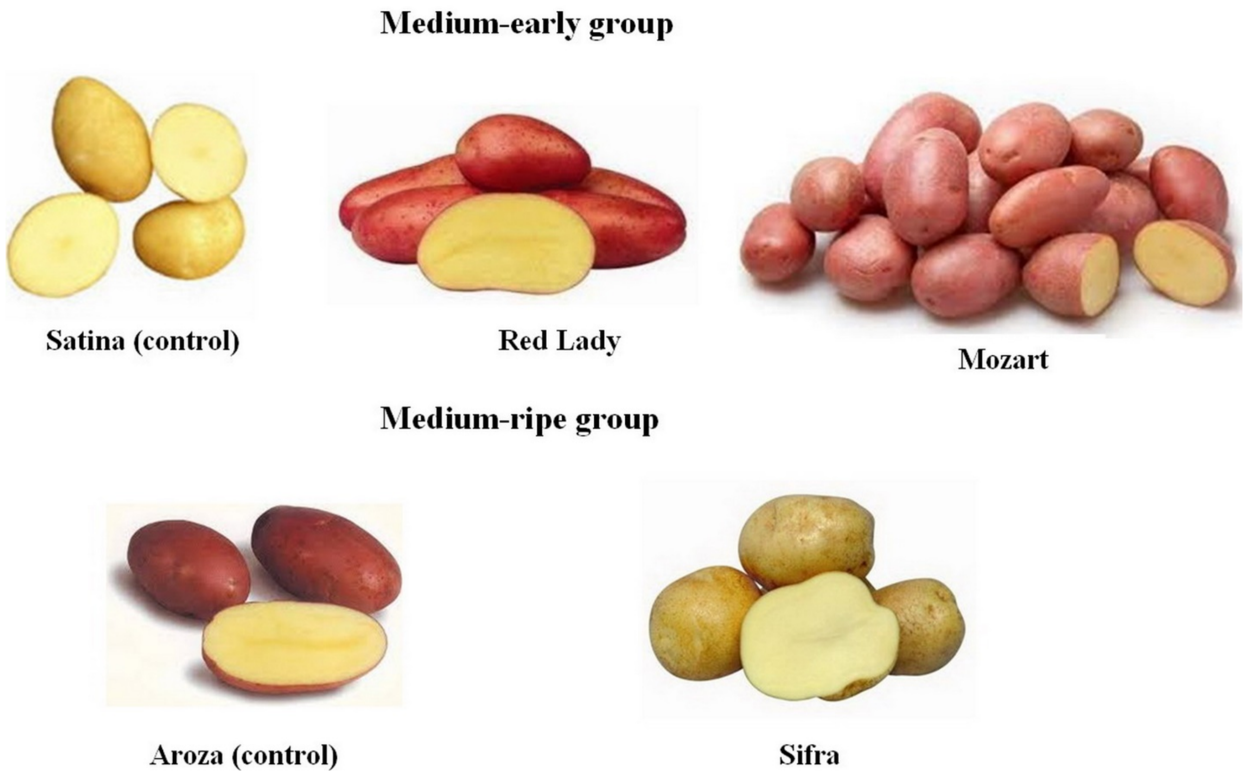

Figure 1 Pictures of potato tubers two groups of ripening.

RESULTS AND DISCUSSION

The biochemical indices of the potato tubers were determined before storage and after 2, 4 and 6 months. The dynamics changes of DM in potato tubers in the experimental varieties were presented in **Table 1**.

According to the research of L. N. Kozlova **(Kozlova, 2005)** on the level of DM accumulation in potato tubers is mainly influenced by the variety of potato (their influence is 46%**)**, the interaction of weather conditions and the place of cultivation – 29% and the combination of these factors – 12%. Other researchers indicated that the most important factors influencing the accumulation amount of dry matter in the potato tubers are varietal characteristics **(Wurr, Beanand Allen, 1978; Mareček, at al., 2015)**, fertilizers and their composition **(Kleinkopf, Westermann and Dwelle, 1981; Pobereźny and Wszelaczyńska, 2011)** and growing zone **(Dinesh, et al., 2005)**.

Our results show that during the storage of tubers potatoes of experimental varieties there was a decrease in the amount of DM, but the intensity of their change was different.

The ripeness group had a significant effect on DM accumulation. Thus, on average in the group of medium-early, at the beginning of storage, the DM content was – 23.5%, and in the group of medium-ripe – 29.3%.

At the end of storage average values of DM depend on the group were 21.1% and 25.9%, respectively. Relative losses in the two groups had averaged values from 9.8 to 11.7% over the whole period of storage. The difference in losses between the individual varieties was more significant, ranging from 2.1% (Mozart**)** to 3.6 % (Aroza).

Particularly intense was the loss of DM in the third storage period from 4 to 6 months, which can be explained by the intensification of physiological processes in potato tubers in the spring. The effect of the ripeness group on the magnitude of the loss was not established. They were affected by the initial amount of DM: than larger quantities were present before storage therefore they were more lost during the storage period.

The basis of the DM in the potato tubers presented starch **(Šimková, et al., 2013; Bhattacharjee, et al., 2014)**.

Its content correlates with quantities of DM and the difference between DM and starch is about 5-9 absolute percent.

In our studies, the average content of starch in the potato tubers, depending on the ripeness group, increased from 16.5% in the medium-early to 23.7% in the medium-ripe **(Table 2)**. This indicator was more dependent on a variety.

The obtained results indicate that the index of starch in the tubers varieties which apply to medium-ripe groups sharply differ: from 21.8% (Sifra**)** to 25.5% (Aroza) **(Table 2)**. In the medium-early group, this difference was smaller – from 15.5% (Mozart**)** to 17.7% (Red Lady).

Storage for 6 months did not cause significant changes in the starch of the tubers. Thus, during three years of research an average of the relative losses were: in the medium-early group – 1% but in the group medium-ripe – 1.9%. The high starch content after 6 months of storage had the varieties of Aroza (23.3%) and Sifra (20.1%), which makes it possible to recommend these varieties for processing with obtaining starch and alcohol.

The content of CP in potato tubers was from 1.9% to 2.2% by weight and more than half of its total content was protein **(Vlasyuk, Vlasenko and Mitsko, 1979)**. The amount of protein that accumulation in potato tubers mainly depends on agro-ecological conditions of cultivation **(Bártová, et al., 2009)**, fertilizers, and their composition **(Ahmed, et al., 2009; Petropoulos, et al., 2020)**.

Table 1 Dynamics of DM in potato tubers, %.

Variety	Before storage	Duration of storage, days 60	120	180
		medium-early		
Satina – control	23.1 ±0.11*	22.6 ±0.32*	21.9 ±0.47*	20.8 ±0,34*
Red Lady	25.1 ±0.05*	24.3 ±0.31*	23.6 ±0.35*	22.4 ±0,28*
Mozart	22.2 ±0.31*	21.7 ±0.26*	21 ±0.45*	20.1 ±0,33*
		medium-ripe		
Aroza – control	31.1 ±0.22*	30.2 ±0.21*	29 ±0.22*	27.5 ±0,29*
Sifra	27.4 ±0.23*	26.6 ±0.28*	25.5 ±0.33*	24.2 ±0,31*

Note: * denotes statistically significant difference at *p* <0.05 level.

Table 2 Dynamics of starch substances in potato tubers, %.

Variety	Before storage	Duration of storage, days 60	120	180
		medium-early		
Satina – control	16.3 ±0.26*	16.2 ±0.22*	15.9 ±0.34*	15.4 ±0.48*
Red Lady	17.7 ±0.26*	17.5 ±0.26*	17.0 ±0.26*	16.3 ±0.34*
Mozart	15.5 ±0.2*	15.4 ±0.27*	15.2 ±0.43*	14.8 ±0.38*
		medium-ripe		
Aroza – control	25.5 ±0.26*	25.1 ±0.33*	24.4 ±0.34*	23.3 ±0.22*
Sifra	21.8 ±0.34*	21.6 ±0.23*	21.0 ±0.3*	20.1 ±0.45*

Note: * denotes statistically significant difference at *p* <0.05 level.

Table 3 Dynamics of CP in potato tubers, %.

Variety	Before storage	Duration of storage, days 60	120	180
		medium-early		
Satina – control	1.8 ±0.06*	1.9 ±0.15*	1.9 ±0.2*	2.0 ±0.18*
Red Lady	1.5 ±0.13*	1.5 ±0.11*	1.7 ±0.13*	1.8 ±0.2*
Mozart	1.7 ±0.06*	1.9 ±0.1*	2.0 ±0.13*	2.1 ±0.15*
		medium-ripe		
Aroza – control	2.0 ±0.07*	2.0 ±0.16*	2.1 ±0.11*	2.2 ±0.14*
Sifra	1.6 ±0.13*	1.6 ±0.06*	1.7 ±0.14*	1.9 ±0.11*

Note: * denotes statistically significant difference at *p* <0.05 level.

Analysis of the content of CP indicated the low difference between these indexes between two groups of maturity **(Table 3)**.

An average during three years of research, its quantity was in the group of medium-early – 1.7% and in the group of medium-ripe – 1.8%. The highest content of CP was observed in the tubers of the 2016 harvest, which confirms its dependence on from conditions of the growing season. The obtained results are confirmed by conclusions of other researchers **(Eliseeva, 1996)**, that indicate the influence of rainfall, temperature conditions during vegetation on the accumulation of CP.

In the process of storage of tubers potato of experimental varieties, the content of CP increased and especially intensively in the period from 4 to 6 months **(Table 3)**. This result is in agreement with the results of the researches obtained by S.F. Polishchuk, which indicates that the maximum content of CP in tubers accumulates in March **(Polishchuk, 1986)**.

The sugar content of the potatoes can vary greatly depending on the variety, the technology of cultivation (fertilizers), the state of the tubers and the storage conditions **(Dogras, Siomos and Psomakelis, 1991; Ohara-Takada, et al., 2005; Galdón, et al., 2010; Muttucumaru, et al., 2013; Mareček, et al., 2013)**. Young tubers of potatoes have more sugar than ripening tubers. Tubers that have higher sucrose content than monosaccharides and have better keeping capacity **(Sowokinos, 1978; Richardson, Davies and Ross, 1990)**.

The highest importance on the ability to accumulate monosaccharides as a result of starch hydrolysis at low storage temperatures in the tubers has varietal features. Thus, the researchers recorded an increase in the sugar content in the potato tubers of the Yantarniy variety from 0.55% to 3.48% during storage at low temperatures, which made them unsuitable for industrial processing **(Gusev and Metlitsky, 1982)**.

In our investigations, the TS content an average during three years of research was 0.43% in the medium-early group and 0.4% in the medium-ripe group **(Table 4)**.

Thus, on average, during the three years of investigation, the content of TS did not differ significantly between the ripeness groups but had differences between the varieties. The highest content of sugars was contained in the potatoes of the Satina variety (0.65%) and the lowest in the Sifra (0.22%) and Mozart (0.23%) varieties. The content of RS in potatoes ranged from 0.07% to 0.28%, which makes them suitable for industrial processing **(Table 5)**.

The storage process was accompanied by an increase in the content of both total and reducing sugars.

Table 4 TS dynamics in the potato tubers, %.

Variety	Before storage	Duration of storage, days 60	120	180
		medium-early		
Satina – control	0.65 ±0.2*	0.97 ±0.12*	1.16 ±0.04*	1.37 ±0.07*
±Red Lady	0.41 ±0.21*	0.73 ±0.14*	0.85 ±0.05*	1.17 ±0.05*
Mozart	0.23 ±0.3*	0.55 ±0.26*	0.78 ±0.04*	1.12 ±0.03*
		medium-ripe		
Aroza – control	0.58 ±0.23*	0.94 ±0.2*	0.96 ±0.03*	1.31 ±0.06*
Sifra	0.22 ±0.09*	0.51 ±0.02*	0.78 ±0.05*	0.92 ±0.03*

Note: * denotes statistically significant difference at p <0.05 level.

Table 5 Dynamics of RS in potato tubers, %.

Variety	Before storage	Duration of storage, days 60	120	180
		medium-early		
Satina – control	0.28 ±0.08*	0.43 ±0.04*	0.51 ±0.02*	0.65 ±0.06*
Red Lady	0.18 ±0.02*	0.3 ±0.02*	0.37 ±0.04*	0.52 ±0.04*
Mozart	0.09 ±0.01*	0.21 ±0.03*	0.35 ±0.03*	0.47 ±0.04*
		medium-ripe		
Aroza – control	0.26 ±0.01*	0.39 ±0.04*	0.44 ±0.07*	0.58 ±0.04*
Sifra	0.07 ±0.01*	0.22 ±0.02*	0.33 ±0.04*	0.4 ±0.02*

Note: * denotes statistically significant difference at p <0.05 level.

Table 6 Dynamics of AA in potato tubers, %.

Variety	Before storage	Duration of storage, days 60	120	180
		medium-early		
Satina – control	8.7 ±0.13*	8.2 ±0.33*	7.5 ±0.2*	6.7 ±0.14*
Red Lady	9.1 ±0.33*	8.7 ±0.28*	8.4 ±0.23*	7.5 ±0.17*
Mozart	11.4 ±0.14*	11.0 ±0.29*	10.3 ±0.21*	8.5 ±0.12*
		medium-ripe		
Aroza – control	13.4 ±0.26*	12.5 ±0.21*	11.7 ±0.23*	9.3 ±0.1*
Sifra	9.8 ±0.23*	9.5 ±0.27*	9.1 ±0.27*	7.3 ±0.08*

Note: * denotes statistically significant difference at p <0.05 level.

Table 7 Dynamics of nitrates in potato tubers, $mg.kg^{-1}$.

Variety	Before storage	Duration of storage, days 60	120	180
		medium-early		
Satina – control	74 ±2.32*	68 ±4.17*	63 ±2.67*	56 ±2.35*
Red Lady	85 ±2.66*	76 ±3.35*	72 ±3.12*	61 ±2.15*
Mozart	63 ±2.13*	57 ±2.67*	51 ±4.63*	47 ±2.41*
		medium-ripe		
Aroza – control	71 ±2.44*	64 ±2.56*	57 ±3.35*	49 ±2.83*
Sifra	80 ±4.31*	73 ±3.31*	65 ±3.34*	52 ±2.67*

Note: * denotes statistically significant difference at p <0.05 level.

During the whole storage period, the TS content increased depends on variety from 2 to 5 times but RS increased at least five times and at the end of storage (after 6 months) we obtain from 0.4% to 0.65%.

That is, most varieties were characterized by an excess of optimum content of sugar 0.2 – 0.4%, which makes them unsuitable for the production of fried potatoes. However, some researchers indicate **(Metlitsky, Gusev and Tektonidi, 1972; Marquez and Añon, 1986)** that a significant deterioration in the color of potato products appears only with the content of RS is 1% and more. Some researchers **(Roe, Faulks and Belsten, 1990)** indicated the effect of fertilizers, especially nitrogen, on the darkening of potatoes during frying.

The amount of vitamin C that accumulates in potato tubers depends on many factors, the main of which are varietal characteristics, fertilizers and their doses, farming systems, zones of cultivation, soil and climatic conditions **(Hamouz, et al., 2009; Macák, Žák and Polláková, 2012)**.

Before storage, the mean content of AA in potato tubers was 9.7% in the medium-early group and 11.6% in the medium-ripe group **(Table 6)**.

The process of potatoes storage was accompanied by a decrease in the amount of AA, which negatively affected the biological value. Its relative losses during the storage

period an average set of 21.9% in the medium-early group and 28.1% in the medium-ripe group, respectively.
The lost of AA depends mainly on varietal characteristics. According to our research during the whole storage period, the greatest losses had potatoes of Aroza variety (30.6%) and the lowest – Red Lady (17.6%).

The content of nitrates in the product determines the level of its safety and is regulated according to sanitary standards. The high content of nitrates presented in the skin of the tuber and the areas of the eyes **(Ilchuk, 1993)**. As a result preparation of French fries and dried potatoes, the content of nitrates reduced by 70 – 80 % but chips by 72 – 76% **(Zabara, 2000)**. The quantity of nitrates in the potato tubers depends on different factors, the main of which are fertilizers and their doses, farming systems, and type of soil **(Yli-Halla, Viikari and Palonen, 1987; Ahmed, et al., 2009)**.

In our experiments, the nitrate content before storage was lower than allowed according to the maximum permissible level and ranged from 63 to 85 $mg.kg^{-1}$ but at the end of storage were 47 – 61 $mg.kg^{-1}$ **(Table 7)**. That is, the relative losses of nitrates during the whole storage period an average were from 25 to 28 %.

CONCLUSION

The results of the effect of storage duration, variety characteristics, and ripeness group on changes in qualitative parameters of potato tubers were established.
The potato tubers of the experimental varieties accumulated different amounts of DM. Their quantity depended on the length of the growing season, that is, the medium-early ones accumulated less (23.5%) and the medium-ripe ones more (29.3%). The process of storage of tubers was accompanied by the loss of DM, especially in the period from 4 to 6 months that explained by the intensification of physiological processes in potatoes in the spring. The effect of the ripeness group on the magnitude of the DM loss was not established.

All potato varieties had a high content of starch. Storage and group of ripening did not significantly affect the level of its losses (medium-early – 1%; medium-ripe – 1.9%). The highest starch content after 6 months of storage characterized two varieties of Aroza (23.3%) and Sifra (20.1%).

The amount of CP in the potato tubers for three years depended on the conditions of the growing season. This indicator increased during storage. Its maximum value we obtain after 6 months and the magnitude of growth over an average of three years in both maturity groups was 0.25 – 0.26%.

The amount of TS depended on the varietal characteristics of the potato: the highest content was characterized by the variety Satin (0.65%) and the lowest – Sifra (0.22%) and Mozart (0.23%). During the whole storage period, the TS content increased depending on the variety from 2 to 5 times, but RS was by 5 times and more.

The amount of AA and its loss during storage depended on the variety. During the storage period, relative losses on average were 21.9% in the medium-early group and 28.1% in the medium-ripe group. The largest losses were potatoes of Aroza (30.6%) and the smallest – Red Lady (17.6%).

Potato tubers had nitrate content less than allowed by the maximum permissible level and during storage, their relative losses were 25 to 28%.

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