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DETERMINING QUALITY INDICATORS OF TABLE GRAPE VARIETIES DURING STORAGE IN A REFRIGERATING CHAMBER IN DIFFERENT VARIANTS

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This study considers determining the quality indicators of table grape varieties when stored in a refrigerating chamber for different variants. The objects were white table grape variety, widely used in Azerbaijan, Ganja table grape variety, pink grape variety – Marandi Shamakhi, as well as the red grape variety Black Asma. Grape varieties stored in the refrigerator were studied according to five options.

Table grape varieties were stored in a refrigerating chamber under conditions of an adjustable gas environment (3–4 % CO_2, 2–3 % O_2) at a temperature of –1 and –2 °C, with air humidity of 90–95 %. It was found that at a temperature inside the pulp of 0+1 °C, the activity of enzymes decreased significantly compared to other options. In addition to the enzyme ascorbate oxidase, the activity of the studied enzymes o-diphenol oxidase, peroxidase, and catalase was 100 % suppressed in the Marandi Shamakhi grape variety. The inactivation of enzyme activity prevented the consumption during respiration of the nutrients that make up the grapes. As a result of slowing down metabolic processes, the appearance, naturalness, and nutritional value of the Marandi Shamakhi grape variety are significantly superior to other varieties.

When storing grape varieties according to option 5, the smallest total losses were observed in the Marandi Shamakhi grape variety. Very few microbiological losses were detected during the storage of the Marandi Shamakhi grape variety compared to other variants and varieties. It was stored in a refrigerating chamber in a controlled gas environment (3...4 % CO_2, 2–3 % O_2, at the temperature of the chamber of –2...–3 °C). A tasting was also carried out to determine the quality indicators when storing grape varieties in different versions; for version 5, the assessment was high

Keywords: Table Ganja, Marandi Shamakhi, Black Asma, ascorbate oxidase, o-diphenol oxidase, peroxidase, catalase

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1. Introduction

Grapes with high nutritional value are widely distributed in most countries of the world, including Azerbaijan [1, 2]. The composition of grapes is rich in useful simple sugars, aliphatic and aromatic organic acids, phenolic compounds, vitamins, carotenoids, macro-microelements, and other useful substances that are easily absorbed by the human body [3] .

Mineral compounds of grapes play an important role in the regulation of metabolic processes in the human body. Mineral compounds are used in the synthesis of proteins, enzymes, hormones, vitamins, and other biological substances necessary for the human body. Since grapes are a quality food product, it is recommended to use them all year round. Therefore, providing the population with high-quality products is an urgent problem of the current viticulture, the effective solution of which can be implemented on the basis of modern technologies.

Providing the population with environmentally friendly products is the main task of each state. The issues of ensuring the safety of table grapes, improving their storage conditions and reducing their losses are of great importance. In this regard, the study of the theoretical foundations and practical issues of grape storage is an urgent problem.

The main difference between grapes and other fruits and berries is that its composition is rich in glucose and fructose, organic acids, mainly phenolic compounds [4]. It is known that phenolic compounds (catechins, anthocyanins, biflavonoids, etc.) contribute to the removal of radiation from the human body [5]. The abundance of minerals in grapes is involved in the synthesis of proteins, enzymes, hormones, and other biologically active substances important for the body [6]. However, people mostly use grapes with high nutritional value as a food crop during the season (1–2 months). Therefore, studies are needed, the results of which will contribute to solving the practical problem of providing people with high-quality grapes all year round. Of particular importance in this case is the study of ensuring the safety of table grapes, improving their storage conditions, and reducing their losses. In this regard, the study of the theoretical foundations and practical issues of grape storage is a relevant task.

2. Literature review and problem statement

One effective way to store table grape varieties is to store them in a controlled gaseous environment. Researchers from different countries conduct numerous studies to study the effect of high doses of carbon dioxide on the safety of grapes. In the course of research, it was established [7] that the storage conditions of grapes include low temperature, high relative humidity of the air, a modified composition of the controlled gas medium. In the refrigerating chamber these conditions were observed but the temperature inside the grape berry was not studied.

Work [8] reports the results of studies related to investigating the resistance to low negative temperatures of grape varieties of various ecological and geographical groups based on the activity of the enzyme peroxidase and its isoforms. But the activity of other enzymes (oxidoreductase, o-diphenol oxidase, catalase) has not been studied. To do this, the authors studied the dynamics of changes in the activity of enzymes belonging to the class of oxidoreductases, in all three varieties, conducting an analysis once a month from the beginning to the end of the storage of grape varieties.

Storage of grapes in refrigerating chambers with an adjustable gas environment (AGE) is quite rare. Storage under normal conditions [9] involves a normal air environment with a normal content of oxygen in the atmosphere (21 %), carbon dioxide, and other gases. Storage in a controlled gas environment is considered to be the storage of fruits in an environment with a certain concentration of CO_2 and oxygen at a certain temperature. At the same time, one or another gas regime is selected in such a way as to maintain normal respiratory gas exchange, as well as the correct ratio between the temperature and condition of the fruit. However, too low oxygen content in the environment and a high content of CO_2 (more than 10 %) can cause physiological disorders.

Work [10] indicates that in a regulated gas environment, compared to storage in a conventional air environment, the quality of the fruit is better preserved. In addition, the green color is preserved longer, the hydrolytic processes of protopectin decay slow down (the fruits remain solid longer). CO_2 and oxygen also affect the biosynthesis of ethylene in the fruit and its biological effect on the ripening processes.

Of interest are studies [11] on the storage of grapes using a modified atmosphere. White table grapes were stored for 60 days at 0 °C, followed by storage for 7 days in air at 15 °C. To obtain a modified atmosphere (MAP) of 15 kPa O_2 and 10 kPa CO_2, a microperforated polypropylene film (PP) with a thickness of 35 µm with 0.7 g Na_2S_2O 5 kg was used – 1 and without it. A macroperforated film was used as a control. After the end of the shelf life, control samples showed the greatest decrease in quality scores, while gas-treated berries showed slight changes in hardness, pH, titrated acidity, maturity index, aroma, and softness. By the end of the shelf life, there was a strong darkening in the control samples, significant mass loss (9.65 %), a high level of microbiological spoilage (more than 9 %). Therefore, a study on the storage of different grape varieties in the refrigerator for different options under the conditions of AGE is advisable.

Work [12] evaluated the effectiveness of controlled atmosphere (CA) conditions to control rotting of table grapes Early 'Thompson Seedless' (16.5 % soluble dry matter content) and late harvest (19 % DM). Grapes were exposed to 5, 10, 15, 20, and 25 % CO_2 combined with 3, 6, and 12 % O_2. First, the grapes were fumigated with SO_2, and grapes stored in the air were used as controls. Storage conditions did not affect the content of soluble DM or cracking of berries. The main limitations in the storage of table grapes of the Thompson Seedless variety of early harvest were the combs and darkening of the berries as a result of exposure to >10 % CO_2. However, ≥15 % CO_2 was necessary to control the complete decomposition and nesting development regardless of the O_2 concentration. CA was more effective in controlling rot without harmful effects on quality when late harvest grapes were used. A combination of 15 %CO_2 with 3, 6, or 12 % O_2 is recommended for storage up to 12 weeks only for late harvesting of Thompson seedless table grapes; CA should not be used for early commercial grapes.

According to studies [13] and measurements, storage in a controlled atmosphere of AGE leads to a decrease in the intensity of metabolic processes by 2–3 times, significantly increasing the shelf life. Other advantages of this technology are a reduction in the development of physiological and fungal diseases (by 20–25 %). Wilting of grapes, for example, decreases by 20–30 %. Due to the slowdown in dissimilation processes, the fruits retain the original quality of the components (acid, sugar, taste and aromatic substances). At the end of storage, the fruit remains as tasty and fresh as it was at the beginning.

Table grapes are a non-climacteric fruit subject to severe loss of water and quality during post-harvest treatment. Study [14] examined the effect of cold storage in modified atmosphere (MA) at different concentrations of CO_2 (0–20 %) on quality assessed after shelf life at ambient temperature. Organic bunches of table grapes (Italia variety) were packaged in MA bags and stored at 2 °C (±1.0) for 14 days, using MA with 0 % (air), 10 % and 20 % of the original CO_2 concentration. Unpackaged samples were used as controls. The composition of the gas inside the packages was measured periodically. After 7 and 14 days, all packages were opened and airlifted at 20 °C for 3 days: organoleptic, physical, and chemical-food parameters were measured. A significant effect of an atmosphere with a high CO_2 content on the delay in visual quality and attenuation has been shown.

This is the approach used in work [14] but the new study examined the dynamics of changes in the activity of enzymes. They belong to the class of oxidoreductases; all three varieties were analyzed once a month from the beginning to the end of the storage of varieties.

All this suggests that it is appropriate to conduct a study on high-quality storage in five variants under AGE conditions.

3. The aim and objectives of the study

The purpose of our work is to study the qualitative storage of various table grape varieties in a refrigerator with AGE. This will make it possible to suppress or significantly reduce the activity of the enzyme and check the fact that the food components (glucose, fructose, vitamin C, phenolic compounds, etc.) during respiration were consumed much less, compared with other options.

To accomplish the aim, the following tasks have been set:

– to investigate the activity of enzymes before storing table grape varieties;

– to study the content of quality indicators and mineral substances before storing table grape varieties;

– to investigate and improve the activity of enzymes during the storage of table grape varieties in different variants;

– to investigate the reduced content of quality indicators and minerals at the end of storage of table grape varieties in the refrigerating chamber for different options;

– to establish the amount of losses during storage of grape varieties in different versions.

4. The study materials and methods

4. 1. The study object and hypothesis

The object of the study was the widely used in the country white table grape variety – Ganja table, pink grape variety – Marandi Shamakhi, as well as the red grape variety Black Asma.

Table grape varieties were collected from the vineyards of the production company "Amin", operating in the village of Garayeri, Samukh district. Storage of individual table grape varieties was carried out in the refrigerating chambers at NAA Agrotara, operating near the city of Ganja for more than five months.

4. 2. Research methods

The studies were conducted in 2018–2020.

Before storage, grape varieties are sorted, cleaned of diseased berries, packed in special containers weighing 8–10 kg, and placed in refrigerating chambers.

Grape varieties stored in the refrigerating chamber were studied according to five options:

– option I: storage of table grape varieties in refrigerating chambers under conditions in a controlled gas environment – 3–4 % CO_2, 2–3 % O_2;

– option II: storage of table grape varieties in refrigerating chambers under controlled atmosphere conditions – 1–2 % CO_2, 2–3 % O_2;

– option III: storage in the refrigerating chamber, burning sulfur every 7 days, i.e., fumigated with sulfur dioxide [18];

– option IV: storage in the refrigerating chamber, burning sulfur every two weeks (control).

At first, the grapes were examined in four versions. At this time, the temperature of the refrigerating chamber where the grapes were stored was 0 +2 °C, and the humidity of the air was 85–92 %. In these studied versions, the temperature inside the grape berries was +3 – +4 °C, and in some cases even + 5 °C.

Note: As a result of the study, the activity of enzymes in these variants was not sufficiently activated, so it was necessary to study another option;

– option V: storage of table grape varieties in refrigerating chambers in a controlled gas environment – 3–4 % CO_2, 2–3 % O_2, temperature –1 –2 °C, humidity 90–95 %. During the storage period, the temperature inside the grapes was 0 °C, and, in some cases, +1 °C. In this version, when storing grapes in the refrigerating chamber, the freezing process was not observed. With long-term storage of grape berries in the refrigerating chamber, its temperature was regularly checked using the "Posket Test Thermometre" (Fig. 1).

Fig. 1. Halco model 84101 "Pocket Test Thermometre"

The dynamics of changes in the activity of the enzymes ascorbate oxidase, o-diphenol oxidase, peroxidase, and catalase, belonging to the class of oxidoreductase, were registered in all three varieties, conducting an analysis once a month from the beginning to the end of storage of grape varieties (for five months). In addition, quantitative changes in total sugar, including glucose and fructose, titrated acidity, pectin substances, vitamin C from beginning to end a storage of grape varieties [12].

The amount of phenolic compounds in grape varieties was determined by chromatography-mass spectrometry, and the amount of minerals on the Aanalyst 400 atomic adsorption spectrometer (PerkinElmer, USA) [12]. Natural, microbiological, and general losses during storage of grape varieties in different variants were also determined. Tasting of each variety was carried out separately for all variants [13].

5. Results of a study of the quality of storage of various table grape varieties

5. 1. Studying the activity of enzymes before storage of table grape varieties

The composition of grapes with environmentally friendly, high nutritional value is rich in easily digestible simple sugars, organic acids, phenolic compounds, vitamins, macro- and microelements useful for the human body [14]. For people's health, it is very important to provide the population with grapes, which are a valuable food product not only in season but throughout the year. To this end, the quantitative change in the listed quality indicators from the beginning to the end of storage of fully ripened grape varieties was studied. First, the dynamics of changes in the activity of these enzymes during the storage of grapes were studied.

The enzyme ascorbate oxidase (FT.1.10.3.3) is a representative of aerobic dehydrogenases and is widely distributed in plants, including grapes. This enzyme performs an important biological function in the ripening and storage of grapes. Thus, the enzyme ascorbate oxidase catalyzes the conversion of ascorbic acid (vitamin C) to dehydro-L-ascorbic acid.

The enzyme O-diphenol oxidase (FT.1.14.18.2) catalyzes the conversion of a wide range of phenolic compounds to orthoxenone in an aerobic environment. An increase in the activity of the enzyme causes a change in the color of the grapes, and its delay or activity allows fruits and berries, including grapes, to remain in their original state.

Peroxidase (FT.1.11.1.7) is a representative of anaerobic dehydrogenases and is an enzyme that accelerates biological oxidation in the presence of hydrogen peroxide. This enzyme catalyzes the oxidation of polyphenols and a number of aromatic amines in the presence of hydrogen peroxide.

The enzyme catalase (FT.1.11.1.8), formed during respiration in plants, including grapes, breaks down hydrogen peroxide into water and molecular oxygen, protecting the plant from harm. When storing grapes, conditions must be created so that the activity of these enzymes is reduced or completely stopped. Otherwise, an increase in the activity of enzymes leads to a decrease in the amount of vitamin C, phenolic compounds, etc. contained in it [15].

Changes in the activity of these enzymes in the studied grape variety are given in Table 1.

Table 1

Enzyme activity before storage of table grape varieties, μ/mol

No.	Indicators	Grape varieties		
		Table Ganja	Marandi Shamakhi	Black Asma
1	Ascorbate oxidase	0.68	0.55	0.66
2	O-diphenol oxidase	0.74	0.76	0.72
3	Peroxidase	2.20	1.66	2.10
4	Catalase	0.42	0.38	0.33

Values in Table 1 demonstrate that before storing table grape varieties, the examined enzymes of oxidoreductase were in active form. In all three grape varieties, the greatest activity was observed in the enzyme peroxidase, and the weakest activity was noted in catalase.

5. 2. Studying the content of quality indicators before storing table grape varieties

The main indicators of the quality of grape varieties, quantified before storage, are given in Table 2.

Table 2

Content of quality and mineral indicators before storage of table grape varieties g/100 g

No.	Indicators	Grape varieties		
		Table Ganja	Marandi Shamakhi	Black Asma
1	Total sugar	21.4	20.6	19.5
2	Glucose	9.3	8.4	8.2
3	Fructose	9.8	9.6	9.3
4	Titratable acidity	0.74	0.68	0.82
5	Pectin substances	0.28	0.31	0.52
6	Pectin	0.12	0.16	0.31
7	Protopectin	0.16	0.15	0.21
8	Vitamin C	0.074	0.094	0.110
9	Phenolic compounds	0.34	0.42	0.56

Values in Table 2 demonstrate that grape varieties are rich in total sugar. They contain up to 19.5–21.4 g/100 g of total sugar. More than 90 % of all sugar consists of glucose and fructose. Values in Table 2 reveal that fructose content is more than that of glucose in grape varieties, and this is very good. This is because fructose has twice the sweeter taste of glucose. Titrated acidity is of particular importance in the formation of the inherent aroma and taste of grapes [16]. As a result of research, it was found that the acidity of the red grape variety Black Asma is higher than that of white and pink grapes.

The content of mineral substances in table grape varieties was also investigated. These indicators are given in Table 3.

Table 3

Mineral content before storage of table grape varieties, mg/100 cm^3

No.	Indicator	Grape varieties		
		Table Ganja	Marandi Shamakhi	Black Asma
1	Potassium	426.2	456.4	365.1
2	Sodium	18.0	24.8	17.6
3	Magnesium	312.5	386.4	281.6
4	Iron	8.6	10.2	8.7
5	Copper	4.8	6.7	5.2
6	Zinc	1.6	2.3	1.4
7	Iodine	0.2	0.6	0.3

Note: iodine content is measured in μg/100 cm^3

Values in Table 3 demonstrate that the Marandi Shamakhi grape variety is significantly rich in mineral substances, mainly potassium, magnesium, and even iodine, compared to other varieties. Even the indicator of iron of Marandi Shamakhi has a higher value, compared to Table Ganja and Black Asma.

From this point of view, grapes are considered an important food product in the daily human diet. As a result of the lack of mineral substances in the human body, the synthesis of some important enzymes, proteins, vitamins, and other substances is disturbed. They are involved in the metabolic process, which creates conditions for the development of various diseases in humans. Therefore, it is important to have in the daily human diet products of plant origin rich in minerals, including grapes.

5. 3. Investigating a change in enzyme activity during storage of table grape varieties in different versions

With long-term storage of fruits and berries, as well as grapes, in the refrigerating chamber, conditions must be created that suppress the activity of enzymes. Increasing the activity of enzymes creates conditions for the breakdown of quality indicators of food products that are used in respiration. Therefore, the activity of enzymes, mainly oxidoreductase, must be constantly regulated in order to store grapes in the refrigerating chamber for a long time (more than five months). The dynamics of changes in the activity of enzymes during storage are given in Table 4.

Table 4

Change in the activity of enzymes during storage of table grape varieties in different variants, %

No.	Indicator	Variants				
		I	II	III	IV	V
		AGE conditions 3–4 % CO_2, 2–3 % O_2	AGE conditions 1–2 % CO_2, 2–3 % O_2	Burning sulfur in a week 1 time	Burning sulfur in two weeks 1 time	AGE conditions 3–4 % CO_2, 2–3 % O_2, temperature in refrigerating chamber –1...–2 °C
1	2	3	4	5	6	7
Table Ganja						
1	Ascorbate oxidase	84.8	76.3	68.1	+15.4	94.4
2	O-diphenol oxidase	83.8	75.2	66.5	24.6	96.2
3	Peroxidase	80.5	77.1	71.6	+4.8	100
4	Catalase	78.2	72.4	67.4	+15.2	93.8

Continuation of Table 4

1	2	3	4	5	6	7
Marandi Shamakhi						
1	Ascorbate oxidase	86.2	80.6	72.4	+7.8	96.5
2	O-diphenol oxidase	89.6	82.1	72.6	50.5	100
3	Peroxidase	82.4	79.2	78.7	48.2	100
4	Catalase	81.7	78.7	74.5	52.1	100
Black Asma						
1	Ascorbate oxidase	85.2	77.4	70.2	+12.6	95.6
2	O-diphenol oxidase	86.1	74.3	67.8	28.5	100
3	Peroxidase	80.6	75.6	70.4	26.3	100
4	Catalase	78.6	70.5	68.2	+12.4	94.2

The change in the activity of the enzyme on the example of ascorbate oxidase during storage of table grape varieties in different variants is shown in Fig. 2.

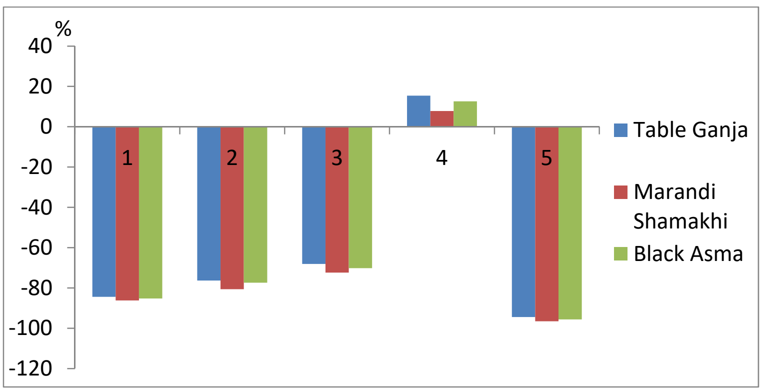

Fig. 2. Change in the activity of the enzyme ascorbate oxidase during storage of table grape varieties in different ways: 1–5 – options. Along the ordinate axis, the enzyme activity is also indicated, %

When storing grape varieties in the refrigerating chamber according to option IV (control), the activity of some enzymes not only did not decrease but even exceeded the original version. Increasing the activity of the enzyme accelerates the use of nutrients, including vitamin C, in the respiratory process.

5. 4. Studying the reduced content of quality and mineral indicators at the end of storage of table grape varieties

As a result of research, it was found that table varieties can be stored not only for five months but also for a longer period. Table 5 gives a reduced content of quality indicators when storing table grape varieties in the refrigerating chamber for various options.

A reduced amount of total sugar when storing table grape varieties in the refrigerating chamber according to different options is shown in Fig. 3.

Table 5

Reduced content of quality indicators at the end of storage of table grape varieties in the refrigerating chamber for different variants, %

No.	Indicator	Variants				
		I	II	III	IV	V
		AGE conditions 3–4 % CO_2, 2–3 % O_2	AGE conditions 1–2 % CO_2, 2–3 % O_2	Burning sulfur in a week 1 time	Burning sulfur in two weeks 1 time	AGE conditions 3–4 % CO_2, 2–3 % O_2, temperature in refrigerating chamber –1...–2 °C
1	2	3	4	5	6	7
Table Ganja						
1	Total sugar content	7.1	8.6	14.1	25.2	2.7
2	Glucose	8.2	10.4	12.8	17.8	2.4
3	Fructose	7.4	10.1	12.4	18.9	2.8
4	Titratable acidity	6.5	7.6	10.2	13.2	4.3
5	Pectin substances	6.8	14.5	16.8	28.5	3.6
6	Pectin	7.6	14.8	17.2	29.4	2.4
7	Protopectin	6.1	12.3	15.6	28.6	2.1
8	Vitamin C	14.4	22.6	48.7	62.5	8.2
9	Phenolic compounds	6.5	10.8	15.5	18.2	2.8
Marandi Shamakhi						
1	Total sugar content	5.2	6.8	8.7	10.4	1.7
2	Glucose	5.1	6.2	9.4	10.6	1.6
3	Fructose	4.6	5.4	8.2	9.5	1.2
4	Titratable acidity	3.4	5.2	7.3	10.7	2.0

Continuation of Table 5

1	2	3	4	5	6	7
5	Pectin substances	2.6	3.8	5.6	10.6	2.2
6	Pectin	1.8	2.6	4.4	10.2	2.4
7	Protopectin	1.6	1.9	5.8	9.8	1.8
8	Vitamin C	8.6	12.5	20.4	30.2	8.5
9	Phenolic compounds	3.2	6.1	10.1	13.4	2.4
Black Asma						
1	Total sugar content	6.3	8.4	12.2	15.1	2.3
2	Glucose	5.8	9.2	10.5	14.2	2.2
3	Fructose	6.4	8.1	9.4	12.5	2.1
4	Titratable acidity	5.5	6.8	10.7	13.6	4.0
5	Pectin substances	6.4	10.2	12.5	14.7	4.2
6	Pectin	5.8	5.4	11.7	15.4	4.1
7	Protopectin	7.1	6.1	12.1	14.6	4.3
8	Vitamin C	12.4	20.3	38.6	46.2	10.1
9	Phenolic compounds	6.8	8.7	10.7	15.2	4.6

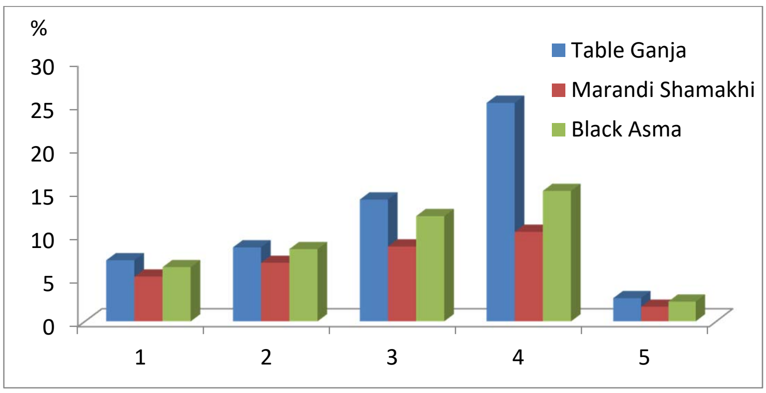

Fig. 3. Reduced amount of total sugar when storing table grape varieties in the refrigerating chamber according to different options: options 1—5

On the axis of the ordinate, the amount of total sugar is indicated, % on the axis of abscissa – options.

Fig. 3 shows that during the storage of grape varieties in the refrigerating chamber, the amount of total sugar, including glucose and fructose, in the V version changed very little.

Grape varieties are rich in minerals, as well as organic compounds. The amount of minerals in plants, including grapes, depends on soil and climatic conditions, specific features of the variety and other factors. Table 6 shows a reduced content of mineral substances during the storage of the studied grape varieties in various ways. Values in Table 6 illustrate that grape varieties are rich in minerals.

Table 6

Reduced mineral content at the end of storage of table grape varieties in the refrigerating chamber, %

No.	Indicator	Variants				
		I	II	III	IV	V
		AGE conditions 3–4 % CO_2, 2–3 % O_2	AGE conditions 1–2 % CO_2, 2–3 % O_2	Burning sulfur in a week 1 time	Burning sulfur in two weeks 1 time	AGE conditions 3–4 % CO_2, 2–3 % O_2, temperature in refrigerating chamber –1...–2 °C
1	2	3	4	5	6	7
Table Ganja						
1	Potassium	10.1	14.5	23.7	32.5	5.4
2	Sodium	8.9	12.4	20.1	28.7	4.8
3	Magnesium	9.5	10.5	18.0	27.2	4.4
4	Iron	6.0	8.1	19.5	28.2	3.2
5	Copper	7.2	7.9	15.1	24.5	3.5
6	Zinc	10.4	11.3	16.4	30.1	5.2
7	Iodine	8.7	9.8	17.2	25.6	4.1
Marandi Shamakhi						
1	Potassium	7.6	9.2	12.1	14.5	3.1
2	Sodium	6.1	7.4	10.3	14.2	2.7
3	Magnesium	7.8	8.2	8.8	10.1	3.2
4	Iron	5.2	7.3	8.2	9.4	9.8
5	Copper	5.8	6.7	10.4	11.7	2.7
6	Zinc	6.4	7.2	9.6	12.5	3.4
7	Iodine	6.3	6.8	8.1	8.7	2.5

Continuation of Table 6

1	2	3	4	5	6	7
Black Asma						
1	Potassium	10.4	12.3	21.7	28.9	6.2
2	Sodium	9.2	13.4	18.6	26.5	5.1
3	Magnesium	8.4	11.5	18.4	24.2	4.6
4	Iron	5.8	7.6	20.5	27.1	3.0
5	Copper	7.9	8.7	14.2	22.3	3.2
6	Zinc	11.5	12.6	18.1	26.7	6.4
7	Iodine	8.8	10.2	12.4	16.8	4.6

As a result of research, it was found that when storing grape varieties in a cold room under AGE conditions, mineral substances are consumed significantly less compared to other options. While storing the Ganja table grape variety under AGE conditions, the amount of mineral substances decreased within 3.2...14.5 %; when stored by burning sulfur in the chamber, this indicator changed within 23.7...32.5 %. The comparison of varieties found that the smallest change in mineral substances was observed in the Marandi Shamakhi variety (Table 6).

5. 5. Investigation and finding the value of losses during storage of grape varieties in different variants

When storing table grape varieties in the refrigerating chamber, the norms of losses were studied according to different options and a tasting of varieties was carried out (Table 7).

The study also determined natural and microbiological losses during the storage of grape varieties in refrigerating chambers. In addition, the grape varieties stored in each variant were tasted on a 10-point scale.

Table 7

Values of losses during storage of grape varieties in different variants, %, estimated by score

No.	Indicator	Variants				
		I	II	III	IV	V
		AGE conditions 3–4 % CO_2, 2–3 % O_2	AGE conditions 1–2 % CO_2, 2–3 % O_2	Burning sulfur in a week 1 time	Burning sulfur in two weeks 1 time	AGE conditions 3–4 % CO_2, 2–3 % O_2, temperature in refrigerating chamber –1...–2 °C
Table Ganja						
1	Natural loss	2.7	3.6	4.8	7.3	1.8
2	Microbiological loss	2.9	3.2	6.4	8.4	1.4
3	Total loss	5.6	6.8	11.2	15.7	3.2
4	Tasting, points	8.7	8.4	8.0	7.4	9.4
Marandi Shamakhi						
1	Natural loss	1.8	2.2	4.1	5.6	1.4
2	Microbiological loss	2.0	2.9	3.1	4.0	0.6
3	Total loss	3.8	5.1	7.2	9.6	2.0
4	Tasting, points	9.2	9.0	8.6	7.8	9.8
Black Asma						
1	Natural loss	3.4	3.8	6.7	9.1	2.8
2	Microbiological loss	1.8	3.6	5.4	8.7	1.8
3	Total loss	6.2	7.4	12.1	17.8	4.6
4	Tasting, points	8.7	8.4	8.0	7.6	9.2

6. Discussion of results of studying the quality of storage of table grape varieties

As evidenced by the data given in Table 1, before the storage of grape varieties, the studied oxidoreductases were in active form. In all three grape varieties, the greatest activity was observed in the enzyme peroxidase, followed by o-diphenol oxidase and ascorbate oxidase, and the weakest activity was noted in catalase.

In the Table Ganja grapes the activity of the enzyme peroxidase was 2.20 μm/mol, for o-diphenol oxidase, this figure was 0.74 μm/mol, for ascorbate oxidase – 0.68 μm/mol, for catalase – 0.42 μm/mol. The indicators are the same in the varieties of Marandi Shamakhi and Black Asma. This can be explained by the fact that an increase in the activity of enzymes leads to a decrease in the amount of vitamin C, phenolic compounds, etc. [15].

The content of quality indicators before storing table grape varieties was investigated. As can be seen from Table 2, the pectin content in Ganja table grapes is much lower than in the Black Asma variety. In the Table Ganja grape variety, the content of pectin substances is 0.12 g/100 g, in Marandi Shamakhi – 0.16 g/100 g, and in the Black Asma variety – 0.31 g/100 g. Marandi Shamakhi and Black Asma grapes are richer in vitamin C compared to the Table Ganja variety.

Also, data in Table 2 show that after total sugar and titratable acidity, grapes contain phenolic compounds. A large number of phenolic compounds in foods, including grapes, inhibits the activity of certain pathogens, even viruses [17, 18]. Therefore, providing people with foods rich in phenolic compounds, including grapes, throughout the year helps protect them from infectious and other diseases [19]. As a result, our studies have found that pink and red grape varieties are richer in phenolic compounds than white grape varieties.

According to the results of the study given in Table 3, the Marandi Shamakhi grape variety is significantly richer in mineral substances, mainly potassium, magnesium, and even iodine, compared to other varieties. It is known that potassium is important in regulating cardiac activity, magnesium – in the excretion of table salt accumulating in the kidneys and other organs, iodine – in the synthesis of thyroid hormones of the thyroid gland [20, 21].

As evidenced by the data given in Table 4, when storing the studied table grape varieties in the refrigerating chamber according to options I, II, III, IV, their activity changed in different ways. When storing grape varieties in the refrigerating chamber according to option IV (control), the activity of some enzymes not only did not decrease but even exceeded the initial version.

Thus, when storing the Table Ganja variety in variant I, the activity of the enzyme ascorbate oxidase decreased by 84.8 % (example: before storage – 0.68 µm/mol, after storage – 0.103 µm/mol, the difference, 0.577; the decrease in enzyme activity was 0.577:0.68·100=84.8 %). We similarly calculated for other enzymes. This indicator was 76.3 % in variant II, 68.1 % for option III. And in the control (option IV), the activity of the enzyme not only decreased but also increased by 15.4 % compared to the original version. Increased enzyme activity accelerates the use of nutrients, including vitamin C, in the respiratory process (Fig. 2).

Values in Table 4 demonstrate that in the control version (IV) during storage in the refrigerating chamber of the Ganja grape variety, the activity of enzymes other than O-diphenyl oxidase increased. And in the Marandi Shamakhi grape variety, an increase in enzymatic activity was established only in the enzyme ascorbate oxidase – 7.8 %. When storing grapes of the Black Asma variety in the refrigerating chamber, the activity of the enzymes o-diphenyl oxidase and peroxidase decreased, and the activity of the enzymes ascorbate oxidase and catalase increased.

Also, values of Table 4 show that during the storage of grape varieties in the refrigerating chamber according to options I, II, III, IV, inhibition of the activity of all enzymes was not observed. And there is no inactivation of enzymes; this is mainly due to the fact that the temperature inside the grapes is +3...+5 °C. Therefore, the activity of enzymes in the proposed V version was investigated (the temperature of the refrigerating chamber –2...–3 °C, and the temperature inside the grapes is 0...+1 °C).

Data in Table 4 show that compared to other variants, the activity of enzymes in variant V decreased more, and some of them ceased to function by 100 %. For example, in the grape variety Marandi Shamakhi, the activity of the enzyme ascorbate oxidase decreased by 95.6 %, and other enzymes stopped their activity by 100 %. Decontamination or inhibition of enzymes prevents the decomposition of nutrient components into the composition of grapes [22, 23]. Therefore, when storing grape varieties in the refrigerating chamber according to the proposed V option, the appearance, nutritional value, and quality indicators of varieties practically do not change.

Values in Table 5 demonstrate that the grape varieties are rich in simple sugars, mainly glucose and fructose, compared to other food components. When storing all three varieties under AGE conditions in the refrigerating chamber, the amount of total sugar is significantly less consumed during respiration compared to other options. The total sugar decreased during storage by 5.2÷7.1 % in variant I, by 6.8÷8.6 % in variant II; in variant V, this figure was less – in the range of 1.7÷2.7 %.

When storing grape varieties in the refrigerating chamber, burning sulfur once a week and once every two weeks, the total sugar in the Ganja table variety fell within14.2÷25.5 %, in Black Asma – 12.2÷15.1 %, and in Marandi Shamakhi – 6.8÷8.7 %.7 %. From the comparison of the options, it was found that during the storage of grape varieties in the refrigerating chamber, the amount of total sugar, including glucose and fructose, in the V variant changed very little. These indicators are shown in Fig. 3.

When storing grape varieties in a refrigerating chamber for different variants, the titrated acidity decreased within 2.0÷13.6 %, and pectin substances – within 2.2÷28.5 %. When comparing variants, it was found that the highest lower titrated acidity, especially pectin substances, is mainly shown in variants III and IV. The titrated acidity decreased by 2.0÷4.3 %, pectin substances decreased by 10.6÷14.7 % in variant V; in other variants, these indicators were 6.5÷28.5 %. During storage, the amount of vitamin C and phenolic compounds decreased, as well as other qualitative indicators.

In version V, vitamin C decreased by 8.2÷10.1 %; in the remaining variants, this figure was 8.6÷62.5 %. When comparing the varieties, it was found that Marandi Shamakhi consumed much less vitamin C in the process of breathing than in other varieties of ah. When storing grapes of the Marandi Shamakhi grape variety in all variants, the content of vitamin C decreased to 8.5÷30.2 %, while in Table Ganja this figure was 8.2÷62.5 %, and in Black Asma 10.1÷46.2 %. As a result of our studies, it was found that during the storage of the Ganja grape variety, the amount of phenolic compounds decreased by 6.5 % in variant I, 10.8 % – II, 15.5 % – III, 18.2 % – IV, and 2.8 % – V. This figure was 2.4÷13.4 % in Marandi Shamakhi and 4.6÷15.2 % in Black Asma.

From the comparison of variants in Table 6, it was found that when storing grape varieties in variant V, mineral substances were consumed less in the process of respiration compared to other options. For example, during the storage of the Ganja table grape variety in variant I, potassium content decreased by 10.1 %; in variant II, this indicator decreased by 14.5 %, in variant III – by 23.7 %, in variant IV – by 32.5 %, in variant V it was much less – 5.4 %. The results obtained were identical with other mineral substances. In the storage of grape varieties in variant V, the amount of minerals in the grape varieties of Marandi Shamakhi is significantly less spent on the breathing process compared to the Ganja table variety and Black Asma.

Data in Table 7 demonstrate that natural and microbiological losses begin with long-term storage of grape varieties in the refrigerating chamber in different variants. From the comparison of varieties, it is known that the lowest natural and microbiological losses during storage were noted in the Marandi Shamakhi grape variety. The total losses during storage for all variants in the Ganja table grape variety ranged from 3.2...15.7 %; in the Black Asma variety, this figure was 4.6...17.8 %, and in the Marandi Shamakhi variety – 2.0...9,6 %. Data in Table 7 show that with long-term storage of grape varieties in a cold room, the natural and microbiological losses for variant I are 1.8...3.4 %, for variant II –2.2...3.6 %, in variant III – in the range of 3.1...6.7 %. In variant IV, it was 4.0...9.1 %, in variant V – 0.6...2.8 %. When storing grape varieties according to variant V, the smallest total losses were observed in the Marandi Shamakhi grape variety. Moreover, a very low level of microbiological losses during storage of the Marandi Shamakhi grape variety compared to other variants and varieties was revealed.

A tasting was also conducted to determine the quality indicators when storing grape varieties in different versions. As a result of the tasting, it was established that when storing grape varieties according to variant I, it was 8.2...9.2 points, according to variant II – 8.4...9.0 points. According to variant III, the tasting acquired 8.0...8.6 points, and according to variant IV – 7.4...7.8 points, according to variant V – 9.2...9.8 points.

Therefore, it is advisable to store grapes in a refrigerating chamber according to variant V proposed by us.

7. Conclusions

1. As a result of research, it has been established that table grape varieties are rich in nutrients necessary for the human body, mainly simple sugars, organic acids, phenolic compounds, minerals, as well as iodine. Before storing fully ripened grape varieties, it has been established that the enzymes ascorbate oxidase, o-diphenol oxidase, peroxidase, and catalase in their composition are constantly active and change in different ways. At room temperature, an increase in the activity of enzymes leads to the breakdown of nutrients in grapes and their use in the process of respiration. From the specific features of enzymes, it is known that they weaken their activity at low temperatures (0 +5 °C). A decrease in the activity of the enzyme prevents the decomposition of organic and inorganic substances in grapes. Therefore, the activity of enzymes was regulated so that better table grape varieties were stored in the refrigerating chamber for a long time with various options.

2. As a result of research, it was found that the acidity of the red grape variety Black Asma is higher than that of white and pink grapes. Compared to the Ganja table variety, Marandi Shamakhi and Black Asma grapes are richer in vitamin C. As a result of research, it was found that pink and red grape varieties are richer in phenolic compounds than white grape varieties.

The Marandi Shamakhi grape variety is much richer in minerals, mainly potassium, magnesium and even iodine, compared to other varieties. It is known that potassium is important in the regulation of cardiac activity, magnesium – in the excretion of table salt that accumulates in the kidneys and other organs, iodine – in the synthesis of thyroid hormones of the thyroid gland.

3. When storing table grape varieties, it was found that the activity of the studied enzymes during storage according to variant V not only decreases compared to other variants but some of them even cease their activity by 100 %. Stopping the activity of enzymes significantly prevented the breakdown of nutrients in grapes. When storing grape varieties according to variant IV, the activity of enzymes not only decreased but in some of them even increased. As a result of the inactivation of enzymes during the storage of grape varieties, the appearance and quality of the Marandi Shamakhi grape variety were superior to other varieties in.

4. Based on the results of the studies, it was found that grape varieties with long-term storage in the refrigerating chamber under AGE conditions (3–4 % CO_2, 2–3 % O_2), at the temperature of the chamber of –1...–2 °C, and the temperature inside the grape berries of 0...+1 °C, food components (glucose, fructose, vitamin C, phenolic compounds, etc.) in the process of respiration were consumed much less, compared with other options. Therefore, it is recommended to store grape varieties according to the method proposed in this research.

It was found that when storing grape varieties according to variant V, in the process of respiration, mineral substances were consumed less compared to other options.

5. As a result of the research, it was found that the amount of natural and microbiological losses during the storage of grape varieties in the refrigerating chamber under AGE conditions (3...4 % carbon dioxide, 2...3 % oxygen, chamber temperature –1...–2 °C) according to variant V, compared to other options, was much less, and the tasting assessment was high.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data Availability

The manuscript has no related data.

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