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IMPROVING THE STORAGE TECHNOLOGY OF PERSIMMON FRUIT (DIOSPYROS KAKI L.) IN THE REFRIGERATION CHAMBER

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Persimmon fruits (Diospyros kaki L.) attract the attention of researchers due to their high nutritional and medicinal value. The composition of persimmon is rich in nutrients. The object of research is the storage technology of persimmon. Fully ripe persimmon varieties Khachia and Khiakume were used as research material. If the activity of enzymes is inhibited or reduced during refrigerated storage using a controlled gas environment, then the consumption of nutrients for respiration will decrease, and the fruits will retain their original appearance. The persimmon varieties used were stored in refrigerators for 5 months in five variants. In persimmon fruits of both varieties, quantitative changes in the main indicators during refrigerated storage were studied. The regularities of changes in the activity of enzymes of the oxidoructase class depending on the composition of the controlled gas medium and the content of phenolic compounds were considered.

As a result of the analyzes, a rational regime for storing persimmon varieties in a refrigerator under CGE conditions with a gas composition of 3–4 % CO_2 and 2–3 % O_2, a temperature of –2...–3 °C and an air humidity of 90–95 % was determined. During the storage period, the activity of all enzymes, except for ascorbate oxidase, completely ceased (except for the catalase enzyme in the Khachia variety). During long-term storage of the Khachia variety in a refrigerator, the activity of the enzyme ascorbate oxidase decreased by 94 %, o-diphenol oxidase and peroxidase decreased by 100 %, catalase by 95.5 %. Ascorbate oxidase activity decreased by 94.5 % in persimmon fruits of the Khiakume variety, and the activity of other enzymes was completely inhibited. To achieve this result, it is important that the activity of oxidoreductases decreases or passes into an inhibitory state. The results make it possible to regulate the quality indicators of persimmon varieties depending on their storage modes and use them to provide people with fresh fruits not seasonally but for a long time

Keywords: persimmon varieties – Khachia, Khiakume, oxidoreductases, total sugar, phenolic compounds

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1. Introduction

Persimmon fruits (*Diospyros kaki L.*), widely distributed in countries with a temperate climate, are of great importance in food production and fresh consumption due to their environmental safety, high nutritional value, and therapeutic and prophylactic properties [1]. Their composition is rich in sugars, vitamins, phenolic compounds, mainly β-carotene, macro- and microelements, as well as iodine, which are necessary for the normal development of the human body. A distinctive feature of persimmon fruits from other fruits is that no chemicals are used during their cultivation and ripening [2]. This is due to the fact that persimmon fruits are significantly rich in phenolic compounds, mainly flavonoids, procyanidins, polyphenols, which are natural antioxidants and have antimicrobial and antiviral properties [3]. Since the composition of this fruit is rich in various representatives of phenolic compounds, it helps eliminate radiation from the human body and reduces the risk of developing malignant tumors and dangerous viruses [4].

Mineral substances of persimmon fruits are involved in the synthesis of proteins, enzymes and hormones that are important for the human body. The fact that persimmon fruits are rich in iodine is considered an indispensable natural medicine for the treatment of goiter [5].

Enzymes belonging to the class of oxidoreductases catalyze redox reactions. Most representatives of oxidoreductases have been widely studied in the food industry, in fruits and berries. Ascorbate oxidase (FT.1.10.3.3.), being a representative of aerobic dehydrogenases, is one of the most important enzymes that play an important role in fruit ripening and processing. Aerob dehydrogenases or oxidases take hydrogen from oxidized substances and transfer it to oxygen. Anaerobic dehydrogenases take hydrogen from oxidized substances and transfer instead of oxygen to another acceptor, other enzymes. Oxygen does not participate in the reactions they catalyze. The enzyme ascorbate oxidase belongs to aerobic dehydrogenases and catalyzes the conversion of ascorbic acid (vitamin C) into dehydro-L-ascorbic acid. Therefore, an increase in the activity of this enzyme is not desirable; the quantitative content of vitamin C decreases.

The enzyme o-diphenol oxidase (FT.1.14.18.2.) belongs to aerobic dehydrogenases and catalyzes the conversion of a wide range of phenolic compounds, including ortho- and para-diphenols, into o-quinone. Peroxidase (FT.1.11.1.7.) refers to anaerobic dehydrogenases and catalyzes the oxidation of polyphenols and a number of aromatic amines in the presence of hydrogen peroxide. Its action takes place in an oxygen-free environment. Persimmon fruits are rich in natural antioxidant phenolic compounds, which are also inhibitors. The choice of the optimal storage mode will help reduce the activity of these enzymes.

The enzyme catalase (FT.1.11.1.6) neutralizes hydrogen peroxide, which is formed during metabolism in plants, including persimmon, by splitting it into water and molecular oxygen. This is especially important due to the fact that, as a result of the action of H_2O_2, membrane lipids undergo peroxidation, which damages the structure of membranes and disrupts them [6].

Therefore, research into this area is the most relevant. One of the reasons for the limited consumption of persimmon fruit is due to its seasonality and unimproved storage methods. Fresh persimmon fruits with high nutritional value are consumed only for 1–2 months. Most remain at the top of the tree, deteriorate, and are thrown away as waste. From the point of view of a healthy lifestyle, people should use this valuable food product, not seasonally, but throughout the year. Therefore, the use of fresh persimmon fruits in the daily diet, as well as the improvement of the technology of its storage in the refrigerator, is an urgent problem.

2. Literature review and problem statement

In [7], it is indicated that with a lack of iodine in the human body, the synthesis of thyroid hormones – thyroxine and others – is disrupted. This reason is due to the fact that the human body does not have the ability to synthesize iodine. Therefore, it is important to include foods rich in iodine in your daily diet. It is important to note that among the foods of plant origin available to people, persimmon fruits are the richest in iodine. The mineral composition of persimmon is rich not only in iodine but also in potassium and magnesium. Potassium plays an important role in strengthening the heart muscle, regulating cardiac activity, and magnesium plays an important role in removing salts accumulated in the kidneys and other organs of the human body. From this point of view, persimmon can be considered a strategic food product. The article points out that when persimmons are stored under normal refrigeration conditions, when stored using carbon dioxide, the quantitative content of minerals decreases. Therefore, it is important to choose a storage mode under which the mineral composition of persimmon fruits will be at a high level.

In [8], the dynamics of changes in the activity of ascorbate oxidase, o-diphenol oxidase, peroxidase, and catalase enzymes belonging to the class of oxidoreductases in plant raw materials were studied. It is known that in all living organisms the metabolic process proceeds with the participation of enzymes. An increase in the activity of enzymes contributes to the consumption of nutrients in raw materials for the respiration process. Similar dynamics of changes in enzymes are observed in persimmon fruits. The work does not indicate the ways of inhibition or decrease in the activity of enzymes of the class of oxidoreductases. Therefore, it is important to take into account the methods and ways of enzyme inhibition.

Work [9] considers pectin substances of persimmon fruits. Persimmon fruits are rich in pectin. Pectin substances are representatives of heteropolysaccharides and consist of pectin and protopectin and their salts – pectate and pectinate. As persimmon fruits ripen, the protopectin included in its composition undergoes enzymatic hydrolysis and turns into pectin and pectinic acid. During ripening and high-quality storage of persimmon fruits, such conditions should be created so that pectin substances remain sTable for a long time. The authors focus on the importance of consuming semi-finished products with a high content of micronutrients based on fruit and vegeTable raw materials as a replenishment of the body with useful substances, including pectin. Such cooked foods can be included in the daily diet of people but will not be as effective as fresh ones. This is not a rational way to solve the problem of providing people with a complete food product.

In [10], it is noted that in order to provide people with products rich in vitamins, minerals, sugars, and other important components, it is possible to obtain juice from persimmon fruits and use it throughout the year. The biochemical parameters of persimmon fruits before and after processing are considered, where it can be seen that after heat treatment, the quantitative indicators of the finished product were lower than in fresh fruits. In addition, consumers have different preferences, and not everyone can afford to use juice. Therefore, the use of fresh persimmon fruits and the improvement of long-term storage methods come to the fore.

According to the literature data [11], the edible parts of fruits contain a large amount of polyphenols (antioxidants), vitamins, and minerals that can have a beneficial effect on human health when used systematically. Persimmon fruits are also rich in polyphenols, thanks to which they are not subject to microbiological spoilage. The author in the work explores the method of preserving the nutritional value of fruits, because drying is also one of the methods for long-term storage of fruits and berries for the longest possible time to provide people with environmentally friendly products. However, during drying, due to the removal of moisture, the initial quality indicators change. There is a need to choose the right method for storing fruits fresh.

In [12], it is recommended to choose such a progressive technological regime during storage in order to reduce the intensity of respiration of persimmon fruits. The authors note that the activity of enzymes in fruits and vegeTables varies in different ways, so it is important to regulate the activity of enzymes in order to maintain the quality of fruits for a long time. Ripe fruits are rich in biochemical parameters. However, the role and significance of these components during the storage of fruits are poorly understood. An increase in the activity of enzymes of the class of oxidoreductases and others contributes to the splitting of the main indicators of product quality by oxidative, hydrolytic, and other ways, as well as their expenditure on the breathing process. In the cited work, phenolic compounds of persimmon fruits, which play an important role in the inhibition of enzymes of the oxidoreductase class, were not studied in detail.

In [13], the influence of the temperature regime of storage on the loss of nutrients of stored raw materials was studied. It is clear from the studies that, in addition to the temperature regime, the preservation of quality components is also affected by humidity, varietal characteristics, proper stacking, and other important storage indicators.

In [14], they indicate that the consumption or decomposition of pectin substances in the process of respiration leads to the fact that persimmon fruits soften and then change their color. This principle is explained in [15] by the fact that the activity of enzymes that break down pectin substances, mainly pectinesterase, increases. In the course of research, it was found that the process of softening persimmon fruits does not proceed so quickly. The reason for this is that persimmon fruits are rich in phenolic compounds.

In [16], it is indicated that phenolic compounds have the ability to weaken or even inhibit the activity of oxidative enzymes, including pectin enzymes. After sugars, persimmon fruits contain the most phenolic compounds. It is the high content of phenolic compounds that protects the fetus from various diseases. The specific characteristics of this fruit are associated with individual representatives of phenolic compounds. This fruit is rich not only in polyphenols but also in representatives of monomeric phenolic compounds. The cited paper indicates that the formation of antioxidant properties of fruit juices rich in phenolic compounds depends on the amount of phenolic compounds of tannins. However, pasteurization and sterilization contribute to a decrease in the antioxidant activity of phenolic compounds. This review does not consider methods for preserving the antioxidant activity of phenolic compounds during fresh storage of fruits.

Work [17] considers the representatives of monomeric phenolic compounds, catechins and leucoanthocyanins, as well as the representatives of biflavonoids, procyanidins. Phenolic compounds, like vitamin C, are organic compounds with high antioxidant, antimicrobial, and even antiviral properties. The lack of phenolic compounds and vitamin C in food products not only negatively affects the quality of the product but also makes them prone to diseases. The authors in the paper point out that the astringent properties of persimmon are mainly associated with catechins. It is important to note that with prolonged non-eating of foods rich in phenolic compounds, immunity decreases, conditions are created for the development of pathogens and viruses. When storing plant materials rich in phenolic compounds, it is important that the quantitative decrease be minimal since phenolic compounds are oxidoreuctase inhibitors. Studies have shown that when storing berries under cold conditions, the amount of phenolic compounds decreases. During refrigerated storage, it is important to choose such a mode and composition of gases in which the consumption of phenolic compounds for metabolic processes was minimal.

In [18], a review of the benefits of persimmon and its processed products was carried out with an emphasis on the digestibility of essential nutrients and biologically active compounds. It is recommended to maintain the health of people to regularly eat foods rich in simple sugars, vitamins, minerals. The use of persimmon puree as an additive to bakery products reduces the duration of fermentation due to simple sugars and lengthens the shelf life of finished products due to phenolic compounds. Quantitative changes in simple sugars and vitamins have been studied in the work, but the importance of phenolic compounds and their preservation has not been given due attention. Cooked persimmon puree does not have antioxidant activity. The bioavailability of all antioxidant compounds in fresh persimmon fruits is higher than in heat-treated.

In [19], the authors analyzed the inhibitory effect of tannins extracted from Niuxin persimmon on pancreatic lipase. This critical enzyme is associated with hyperlipidemia and obesity. It has been established that tannins extracted from persimmon have a high affinity for pancreatic lipase and inhibit the activity of this enzyme; the interaction was spontaneous through non-covalent bonds. Thus, the binding and inhibiting ability of persimmon tannins on lipid digestive enzymes can be effective for the treatment and prevention of obesity.

In [20], the authors carried out a technological and biochemical evaluation of the fruits of oriental persimmon varieties for use in the food industry. The specific gravity, comparative keeping quality, transportability, volume change during storage, natural loss of persimmon fruits (Zanji Maru, Jiro, Khiakume, and Khachia), acidity, sugar content, vitamins and minerals were determined. However, the content of phenolic compounds and changes in enzyme activity are not shown, as well as recommendations for storing persimmon fruits using modern methods.

Thus, persimmon fruits are rich in organic and inorganic substances useful for the human body, mainly simple sugars, iodine, and certain representatives of phenolic compounds. Persimmon fruits and products of their processing should be included in the daily diet of a person. An analysis of the literature data confirms that the nutritional value of persimmon and its processing products has been sufficiently studied. However, there is no data on long-term storage of persimmon fruits. In addition, studies in the field of persimmon storage and the effect of enzyme activity on the storage process have not been carried out. For long-term high-quality storage of food products, the activity of enzymes involved in the metabolic process must be constantly regulated during the entire storage period.

Therefore, in order to further substantiate the method of long-term storage of persimmon fruits, which inhibits the activity of enzymes of the oxidoreductase class and contributes to the preservation of nutritional value and chemical composition, including phenolic compounds of persimmon fruits, it is necessary to improve the technology of persimmon storage.

3. The aim and objectives of the study

The aim of this study is to improve the technology of storing persimmon fruits in a refrigeration chamber. This will make it possible to provide people with environmentally friendly, highly nutritious persimmon fruits with high organoleptic and quality indicators all year round.

To achieve this goal, the following tasks are solved:

– to determine the quality indicators of persimmon fruits before storage;

– to determine the quality indicators of persimmon fruits with different storage options;

– to determine natural and microbiological losses;

– to substantiate the rational modes of storage of persimmon fruits.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of our research is the storage technology of persimmon fruits. The persimmon varieties Khachia and Khiakume, widely distributed in the territory of the Republic of Azerbaijan, were used as the material for the study.

The research hypothesis is as follows. With long-term refrigerated storage of persimmon fruits in a controlled gas environment, the activity of enzymes of the oxidoreductase class – ascorbate oxidase, o-diphenol oxidase, catalase and peroxidase – is inhibited or reduced. At the same time, nutrients are little spent on the breathing process, persimmon fruits retain their original appearance, and most importantly, the temperature inside the fruit drops to +1 °C. This contributes to the deactivation of enzymes. Phenolic compounds of persimmon fruits, due to a decrease in the activity of the enzyme o-diphenol oxidase, change little quantitatively, and with their antioxidant and antimicrobial properties prevent microbiological spoilage.

It is assumed that it is advisable to use ripe persimmon fruits for storage in a refrigeration chamber. The presence of antioxidant and astringent properties in persimmon is associated with representatives of polymeric phenolic compounds – hydrolyzable and non-hydrolyzable tannins, catechins, and some bioflavonoids from flavonoids. When storing persimmon fruits in a refrigeration chamber, the activity of the studied enzymes in four variants is not completely inhibited. It is important to improve the existing methods of persimmon storage using a controlled gas environment with a change in the gas composition within 3–4 % CO_2, 2–3 % O_2 with a temperature in the refrigeration chamber of –2...–3 °C and a relative humidity of 90–95 %.

4. 2. Studied materials

The varieties of persimmons used were stored in the refrigerators at the NAA Agrotara enterprise, located near the city of Ganja. For storage, persimmon varieties were separately pre-sorted, cleaned, and packed in special containers weighing 8–10 kg, and placed in refrigerators. Persimmon varieties were stored in the refrigerator for 5 months (answer to remark 5). Persimmon fruits ripen in November, early December. In the winter months and early spring, weather conditions make it possible to store fruits under normal conditions, but with an increase in temperature, it is imperative to store in a refrigeration chamber. Studies have shown that it is not advisable to store persimmons for more than five months, as the markeTable appearance of the product is deteriorating.

The studies were carried out in 2018–2022 at the Department of Food Engineering and Expertise of the Azerbaijan Technological University, as well as in the laboratory of the Georgian Scientific Research Institute.

4. 3. Methods for studying the quality indicators of persimmon fruits during long-term refrigerated storage

The persimmon varieties Khachia and Khiakume were stored in a refrigeration chamber in 4 variants. In subsequent years, it became necessary to apply another option. Thus, in the course of the study, persimmon fruits were stored in the refrigerator in 5 variants:

– variant I: Storage of persimmons in a refrigeration chamber in a controlled gas environment (CGE) with a gas composition of 3–4 % CO_2 and 2–3 % O_2;

– variant II: Storage of persimmons in a refrigeration chamber under CGE conditions with a gas composition of 1–2 % CO_2 and 2–3 % O_2;

– variant III: storing persimmons in a refrigeration chamber by burning sulfur every 10 days;

– variant IV: storing persimmons in the refrigerator under normal conditions.

During long-term storage of persimmon varieties in a refrigeration chamber, the temperature inside the fruit was constantly determined using a pocket test thermometer "Pocket Test Thermometre".

Qualitative indicators of persimmon fruits were studied for all variants.

In the period from the beginning to the end of the storage of persimmon fruits of both varieties, the following was studied:

– dynamics of changes in the activity of some enzymes of the class of oxidoreductases – ascorbate oxidase, o-diphenol oxidase, peroxidase, catalase [21];

– total sugar by areometric method;

– glucose by iodometric method;

– fructose by colorimetric method;

– pectin substances – by the carbosol method [22];

– vitamin C by dichlorophenolindophenol method;

– phenolic compounds by chromato-mass spectrometry [23];

– cellulose by an indirect technique based on the calculation of the cellulose content from the yield of D-glucose during complete hydrolysis [24, 25];

– minerals on an atomic absorption spectrometer –Aanalyst 400 (PerkinElmer, USA);

– tasting was carried out after storage of persimmon fruits in different variants [26];

– natural and microbiological losses of persimmon fruits during storage were determined for different variants.

It is assumed that during cold storage of persimmon fruits, the activity of oxidative enzymes should have significantly decreased, and some of them should have been in an inhibited state. However, when stored according to the indicated variants in a refrigerator, the temperature of which was 0...+ 2 °C, and the air humidity was 85–92 %, regular determination of the temperature inside the persimmon showed that the temperature inside the persimmon reaches + 3...+ 4 °C, and in some cases even +5 °C. Elevated temperature contributed to an increase in enzyme activity, and ultimately the consumption of nutrients, including total sugar and phenolic compounds. Therefore, it became necessary to choose the optimal mode of refrigerated storage, so that the temperature inside the fruits was about 0...+1 °C. Thus, we chose the 5th variant of storing persimmon varieties in a refrigeration chamber under CGE conditions with a gas composition of 3–4 % CO_2 and 2–3 % O_2, a temperature of –2...–3 °C, and an air humidity of 90–95 %.

5. Results of a scientific and experimental study of the possibility of storing persimmon fruits with different variants

5. 1. Analysis of the qualitative indicators of persimmon varieties Khachia and Khiakume

Table 1 gives changes in the activity of oxidative enzymes in fully ripe fruits of the Khachia and Khiakume persimmon varieties.

Table 1

Activity of enzymes of ripe persimmon fruits, μmol/sec

No.	Indicators	Persimmon varieties	
		Khachia	Khiakume
1	Ascorbate oxidase	0.66	0.55
2	O-diphenol oxidase	0.74	0.72
3	Peroxidase	2.10	1.98
4	Catalase	0.44	0.36

Data in Table 1 show that the highest activity of the peroxidase enzyme was recorded in fully ripe persimmon fruits, followed by the enzymes o-diphenol oxidase and ascorbate oxidase. The lowest activity was noted in both persimmon varieties in the catalase enzyme. While in persimmon fruits of the Khachia variety the activity of the peroxidase enzyme was 2.1 μmol/sec, for diphenol oxidase this figure was 0.74 μmol/sec, for ascorbate oxidase – 0.66 μmol/sec, and for catalase – 0.44 μmol/sec .

These indicators were identical for the Khiakume variety. Data in Table 1 show that all the studied enzymes are more active in the Khachia variety than in the Khiakume variety. For example, while the activity of the peroxidase enzyme was 2.1 μmol/sec in the Khachia variety, this figure in the Khiakume variety was 1.98 μmol/sec. Accordingly, ascorbate oxidase activity was 0.66 μmol/sec and 0.55 μmol/sec, 0.74 μmol/sec and 0.72 μmol/sec for o-diphenol oxidase, and 0.44 μmol/sec and 0.36 μmol/sec for catalase.

The significant reduced activity of all the studied enzymes in the Khiakume variety is explained by the fact that the fruits of this variety are rich in antioxidant substances, mainly phenolic compounds. The study also examined some of the biochemical components in mature persimmon varieties. These indicators are given in Table 2.

Table 2

Some biochemical parameters of persimmon fruits, g/100 g

No.	Indicators	Persimmon varieties	
		Khachia	Khiakume
1	Total sugar	20.8	20.5
2	Glucose	8.1	7.6
3	Fructose	8.8	8.5
4	Pectin substances	0.69	0.71
5	Pectin	0.35	0.36
6	Protopectin	0.34	0.35
7	Vitamin C	0.082	0.078
8	Phenolic compounds	0.84	0.82
9	Cellulose	0.32	0.36

Data in Table 2 demonstrate that the composition of persimmon fruit is rich in nutrients and total sugar. Glucose and fructose form the basis of total sugar. More than 90 % of the total sugar in persimmon fruits is glucose and fructose. In persimmon fruits, these simple sugars are in a free state, and this is the main indicator of the nutritional value of persimmon fruits.

There was no difference in total sugar content between the two varieties. While the fully ripe Khachia variety had a total sugar of 20.8 g/100 g, in Khiakume this figure was 20.5 g/100 g. Table 2 shows that the Khachia and Khiakume persimmon varieties are also rich in other nutritional components.

We learnt from Table 2 and Fig. 1, 2 that the content of glucose and fructose in the composition of persimmon fruits is higher. Persimmon fruits contain more fructose than glucose. While persimmon fruits contain glucose in the range of 8.1÷7.6 g/100 g, the amount of fructose is 8.8÷8.5 g/100 g. The content of more fructose in persimmon fruits has a positive effect since fructose is twice as sweet as glucose. Therefore, the fact that fully ripened persimmon fruits have a sweet taste is due to the fact that they contain more fructose.

Table 2 demonstrates that the Khiakume persimmon variety is relatively rich in pectin than the Khachia variety. While the Khiakume variety contains 0.71 g/100 g of pectin, in the Khachia variety this figure was 0.69 g/100 g. The content of pectin and protopectin in both varieties was almost the same. While the amount of total pectin in the varieties Khachia and Khiakume was 0.35–0.36 g/100 g, the content of protopectin changed accordingly within the range of 0.34 to 0.35 g/100 g.

One of the main quality indicators of persimmon fruits is their richness in vitamins. To this end, in ongoing studies, quantitative changes in vitamin C in fully ripened persimmon fruits were studied. Vitamin C is known to be important for a healthy and long life. Therefore, this vitamin is also called the vitamin of life. Data in Table 2 show that the Khachia variety is richer in vitamin C than the Khiakume variety. While the Khachia variety contained 0.082 g/100 g of vitamin C, in the Khiakume variety this figure was 0.078 g/100 g.

Table 2 demonstrates that in terms of quantitative content, after common and simple sugars, phenolic compounds occupy the second place. As a result of the analyzes, it was found that there was no greater difference in the amount of phenolic compounds in both varieties. So, while in the Khachia variety the content of phenolic compounds was 0.84 g/100 g, in the Khiakume variety this figure was 0.82 g/100 g.

Persimmon fruits are also rich in cellulose. As persimmons ripen, the cellulose content in it gradually decreases and turns into other components, mainly sugar. Cellulose is less in juice and pulp and more in persimmon peel. Compared to the Khachia variety, the Khiakume variety was found to contain more cellulose. So, while the Khachia variety had 0.32 g/100 g of cellulose, the Khiakume variety had 0.36 g/100 g.

In the course of the study, the quantitative changes in the mineral substances of the fully ripe varieties of Khachia and Khiakume were also studied in a wider range. These indicators are given in Table 3. Data in Table 3 show that the fruits of both varieties of persimmon are rich in minerals. As a result of the analysis, it turned out that persimmon fruits contain more K, Na, Cu, Mg, Zn, Fe, J.

We learnt from Table 3 that persimmon fruit in terms of minerals is mainly rich in iodine. So, while persimmon fruits of the Khachia variety contain iodine in the amount of 0.250 µg/100 g, in the Khiakume variety this figure is 0.220 µg/100 g. Table 3 demonstrates that the amount of iodine in the Khachia variety is higher than that in the Khiakume variety.

Table 3

The amount of minerals in persimmon fruits, mg/100 g

No.	Indicators	Persimmon varieties	
		Khachia	Khiakume
1	K	134.2	125.4
2	Na	8.4	7.2
3	Cu	0.014	0.010
4	Mg	4.18	3.85
5	Zn	0.008	0.006
6	Fe	0.020	0.017
7	J	0.250	0.220

Note: the amount of iodine in persimmon fruits is measured in µg/100 g

As a result of the research, it was found that the amount of potassium in the Khachia variety is 134.2 mg/100 g, while in Khiakume this figure is 125.4 mg/100 g (Table 3).

Data in Table 3 show that the amount of Mg in the Khachia variety is 4.18 mg/100 g, and in the Khiakume variety it is 3.85 mg/100 g. Persimmon is also rich in Na. Thus, while in the Khachia variety the Na content is 8.4 mg/100 g, in the Khiakume variety this figure is 7.2 mg/100 g. Data in Table 3 prove that the amount of minerals in the Khachia variety is higher than that in the Khiakume variety. With a lack of minerals in the human body, the metabolic process is disrupted, including the exchange of some vital proteins, enzymes, hormones, vitamins, and others. This is the cause of many forms of disease. Therefore, the daily diet of a person should contain foods rich in minerals.

The results of studies of phenolic compounds in persimmon fruits are given in Table 4.

Data in Table 4 show that persimmon fruits are rich in various representatives of phenolic compounds. As a result of the analysis, about 16 representatives of phenolic compounds were found in persimmon fruit varieties. The molecular weights of individual representatives of phenolic compounds were also determined. Table 4 demonstrates that the molecular weight of phenolic compounds varies in different ways. As a result of the research, it turned out that there are 15 representatives of phenolic compounds in the Khachia variety, and 14 representatives in the Khiakume variety. Table 4 demonstrates that persimmon fruits are rich in catechins, gallic, chlorogenic, caffeic, vanillic, and synapic acids.

In the course of the research, it was found that individual representatives of phenolic compounds in the Khachia variety are quantitatively more pronounced compared to the Khiakume variety. While in the Khachia (+) variety there were 265.1 mg/kg of catechin, in the Khiakume variety this figure was 89.2 mg/kg.

As a result of the research, the presence of phenolic compounds was found, which are found only in the Khachia variety and vice versa. While myricetin-3-o-glucoside and stilbene were present in Khachia, these compounds were not registered in Khiakume. Quercetin-3-o-galactoside was found only in the Khiakume variety.

The analysis of literary materials reveals the fact that the presence of antioxidant and astringent properties in persimmon is associated with representatives of polymeric phenolic compounds – hydrolyzable and non-hydrolyzable tannins, catechins from flavonoids and some bioflavonoids.

Table 4

Phenolic compounds of persimmon fruits (in % in relation to the sum of total phenolic compounds)

No.	Indicators	Molecular weight	Persimmon varieties			
			Khachia		Khiakume	
			Determination time, min	Mg/kg	Determination time, min	Mg/kg
1	(+) catechin	263.0	16.152	265.1	15.650	89.2
2	(–) epicatechin	345.1	19.650	359.0	21.670	199.9
3	Gallic acid	343.1	10.405	394.3	12.608	278.6
4	Chlorogenic acid	481.5	16.457	453.0	17.360	361.2
5	Vanillic acid	554.5	17.811	121.4	18.162	434.9
6	Caffeic acid	633.0	18.280	326.7	16.340	463.2
7	p-coumaric acid	670.3	23.587	83.1	21.504	81.7
8	Synapic acid	696.3	26.356	146.9	26.145	69.2
9	Cinnamic acid	747.4	39.975	63.6	38.701	128.7
10	Procyanidin B_1, B_3, B_4	834.0	14.670	128.4	12.565	191.7
11	Procyanidin C_1, T_2, T_3	899.4	16.150	167.3	15.210	134.0
12	Quercetin-3-o-glucuronide	916.7	10.145	101.2	8.140	91.03
13	Quercetin-3-o-glucoside	1011.7	traces	8.2	traces	10.9
14	Epicatechin-3-o-gallate	1118.7	traces	5.77	traces	8.50
15	Myricetin 3-o-glucoside	1085.3	traces	traces	traces	traces
16	Stilbene	1192.2	12.456	8.70	traces	traces

When storing persimmon, one should choose such a mode so that the activity of enzymes that catalyze the breakdown and transformation of biochemical parameters is regulated in any direction, or rather, inhibited. During storage, an increase in enzyme activity causes a decrease in biochemical parameters due to expenditure on the respiration process. Therefore, during storage, it is necessary to constantly monitor the conditions of the gaseous medium regulated in the refrigeration chamber, air humidity, temperature increase and decrease, and other factors. Given the high nutritional value of persimmon fruits, it is very important to provide people with this high-quality, environmentally friendly product.

5. 2. Study of the quality indicators of persimmon fruits during refrigerated storage

After studying the quality indicators of persimmon fruits from each variety, we collected them separately in special containers and placed in a refrigerator. First, we studied the dynamics of changes in the activity of enzymes of the studied class of oxidoreductases at the beginning and at the end of storage of persimmon varieties in four variants.

The main purpose of the study of enzymes during long-term storage of persimmon fruits in the refrigerator with different variants is the regulation of metabolic processes occurring in fruits.

The dynamics of changes in the activity of the studied enzymes are given in Tables 5, 6 and Fig. 1.

Data in Table 5 demonstrate that during storage of the persimmon variety Khachia in a refrigeration chamber, the activity of the studied enzymes in variants I–IV is not completely deactivated. Even when storing persimmon fruits in the refrigerator under normal conditions, the activity of some enzymes not only did not decrease but even exceeded the original version. Thus, while during storage according to variant I of the Khachia variety, the activity of the ascorbate oxidase enzyme decreased by 81.8 %, in variant II this indicator increased by 72.3 %, in variant III – by 63.6 %, and in variant IV – by 18.2 %.

In the variety Khachia, the enzyme o-diphenol oxidase decreased by 86.5 % by the end of storage according to variant I, by 73.0 % in the second variant, by 64.9 % in the variant III, and by 29.7 % in the variant IV.

However, the activity of the peroxidase enzyme in I, II, III variants decreased, and in the IV version, on the contrary, it increased by 14.3 %. The activity of the catalase enzyme tended to gradually decrease during the storage period of the Khachia variety for the four studied variants.

Analysis of data in Table 5 reveals that during storage under CGE conditions of persimmon fruits of the Khachia variety in a refrigeration chamber, compared to other variants, the activity of the enzyme is significantly reduced.

This is mainly due to the fact that carbon dioxide in the refrigeration chamber contributes to a decrease in enzyme activity.

A comparative analysis of the results of studies carried out on I, II, III, and IV variants shows that the activity of enzymes, with the exception of variant IV, gradually decreases. While during storage of the Khiakume variety in variant I, the activity of the ascorbate oxidase enzyme decreased by 76.4 %, in variant II this indicator decreased by 70.9 %, and in variant III – by 61.8 %.

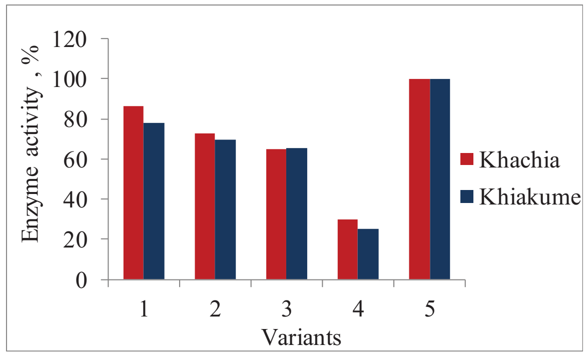

Fig. 1. Decreased activity of the enzyme o-diphenol oxidase during storage of persimmon fruits in a refrigeration chamber according to different variants

In variant IV, the activity of the ascorbate oxidase enzyme increased by 23.6 %. Data in Table 6 and Fig. 5 demonstrate that the activity of the enzyme o-diphenol oxidase decreases during storage of the Khiakume variety under normal conditions, while the activity of other enzymes, peroxidase and catalase, increases.

Table 5

Changes in the activity of enzymes during storage of the Khachia persimmon variety in the refrigeration chamber according to different options, %

No.	Indicators	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2	Under CGE conditions with the composition of gases 1–2 % CO_2; 2–3 % O_2	When burning sulfur every 10 days	Under normal conditions	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2 and temperature in the refrigeration chamber – 2...–3 °C
1	Ascorbate oxidase	81.8	72.3	63.6	+18.2	94.0
2	O-diphenol oxidase	86.5	73.0	64.9	–29.7	100
3	Peroxidase	80.0	74.3	68.6	+14.3	100
4	Catalase	75.0	70.4	63.6	+13.6	95.5

Table 6

Changes in the activity of enzymes during storage of the Khiakume persimmon variety in the refrigerator chamber according to different options, %

No.	Indicators	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2	Under CGE conditions with the composition of gases 1–2 % CO_2; 2–3 % O_2	When burning sulfur every 10 days	Under normal conditions	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2 and the temperature in the refrigeration chamber – 2–3 °C
1	Ascorbate oxidase	76.4	70.9	61.8	+23.6	94.5
2	O-diphenol oxidase	77.8	69.4	65.3	–25.0	100
3	Peroxidase	78.8	72.2	64.6	+18.2	100
4	Catalase	72.2	66.7	61.1	+22.0	100

When storing persimmon fruits in a refrigeration chamber under normal conditions, the activity of enzymes not only does not decrease but even exceeds the original version. This also indicates that during the storage of persimmon fruits, due to the metabolic process continuing in the refrigeration chamber, the process of decomposition and transformation of persimmon nutrients occurs.

The results of the research work made it possible to assume that over the entire period of storage, the activation of enzymes is explained by an increased temperature inside the fruits, which reaches +3 °C...+4 °C, sometimes even +5 °C. Therefore, the regulation of enzyme activity is highly dependent on the ambient temperature. Therefore, the activity of enzymes was re-examined in a slightly modified version (3–4 % CO_2; 2–3 % O_2 in a controlled gas environment, the temperature of the refrigeration chamber is 2...–3 °C, the temperature inside the fruit is 0...+1 °C).

As a result of the study, it was found that during the storage period, the activity of all enzymes, except for ascorbate oxidase, completely stopped (except for the catalase enzyme in the Khachia variety). Thus, while during long-term storage of the Khachia variety in a refrigeration chamber, the activity of the ascorbate oxidase enzyme decreased by 94 %, the activity of o-diphenol oxidase and peroxidase decreased by 100 %, and that of catalase by 95.5 %. When the activity of ascorbate oxidase decreased by 94.5 % in persimmon fruits of the Khiakume variety, the activity of other enzymes was completely inhibited.

Therefore, at the end of storage, the appearance, nutritional value, and quality indicators of both varieties remained practically unchanged. Even with this method, persimmons can be stored in the refrigerator for more than 5 months. The quality of persimmon storage according to this variant depends on the gaseous environment of the refrigerating chamber and the correct regulation of air humidity in it. A further decrease in the activity of enzymes during storage in this environment significantly prevents the breakdown of the nutritional components that make up the persimmon fruits.

In the course of the study, quantitative changes in the main biochemical parameters, except for enzymes, were studied during storage of persimmon varieties according to different variants. Quantitative changes in the main quality indicators during long-term storage of fruits in a refrigerator are given in Tables 7, 8, as well as Fig. 2, 3.

Persimmon fruits contain more sugars than other components. Therefore, quantitative changes in total sugar, as well as glucose and fructose, were studied during storage of persimmon fruits according to different variants.

As a result of the research, it was found that when both varieties of persimmon are stored in a refrigeration chamber under CGE conditions, total sugars, including glucose and fructose, are less spent on the breathing process. While during the storage period in variant I the total sugar decreased by 6.7 %, in variant II by 8.6 %, this figure in variant V in the Khachia variety was 1.9 %, and in the Khiakume variety only 1.5 % (Fig. 2). When storing persimmon fruits in a refrigeration chamber by burning sulfur every ten days, the total sugar in the Khachia variety decreased by 11.5 %, including glucose by 12.3 %, and fructose by 12.5 %. A significant decrease in these indicators was recorded during storage of persimmon fruits in a refrigeration chamber under normal conditions – 17.1÷22.1 %. The smallest change in total sugar, including glucose and fructose, was recorded in the proposed Variant V.

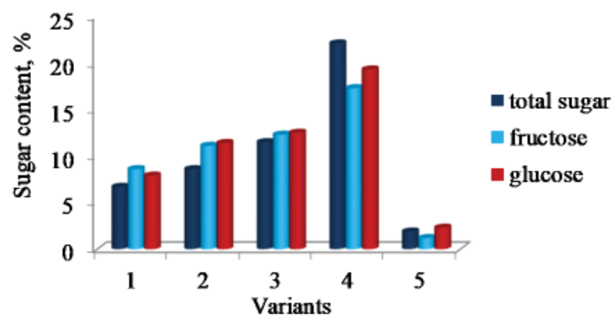

Fig. 2. Quantitative change in sugars during storage of the Khiakume variety in a refrigeration chamber according to different variants

During storage according to variant V, the decrease in sugars in the Khachia variety varied within 1.2–2.3 %, and in the Khiakume variety, within 1.5–2.6 %.

The role of pectin substances in maintaining the quality of persimmon fruits is also great. So, during the period of storage of persimmon fruits, a change in its natural color, softening and deterioration in quality is directly related to pectin substances, as well as protopectin and pectin.

Table 7

Quantitative change in the quality indicators of persimmon fruits of the Khachia variety during storage in a refrigeration chamber according to different variants, %

No.		Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2	Under CGE conditions with the composition of gases 1–2 % CO_2; 2–3 % O_2	When burning sulfur every 10 days	Under normal conditions	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2 and the temperature in the refrigeration chamber – 2–3 °C	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2
1	Total sugar	6.7	8.6	11.5	22.1	1.9	
2	Glucose	8.6	11.1	12.3	17.3	1.2	
3	Fructose	7.9	11.4	12.5	19.3	2.3	
4	Pectin substances	7.2	13.0	17.4	30.4	4.3	
5	Pectin	8.5	14.3	20.0	31.4	5.7	
6	Protopectin	5.9	11.4	18.5	29.4	2.9	
7	Vitamin C	12.2	18.3	24.4	43.9	4.9	
8	Phenolic compounds	7.1	11.9	15.5	30.9	2.4	
9	Cellulose	6.2	9.4	15.6	31.2	3.1	

Table 8

Quantitative change in the quality indicators of persimmon fruits of the Khiakume variety during storage in a refrigeration chamber according to different variants, %

No.	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2	Under CGE conditions with the composition of gases 1–2 % CO_2; 2–3 % O_2	When burning sulfur every 10 days	Under normal conditions	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2 and the temperature in the refrigeration chamber – 2–3 °C	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2
1	Total sugar	6.8	7.3	12.2	21.5	1.5
2	Glucose	7.9	10.5	11.8	17.1	2.6
3	Fructose	9.4	10.6	11.7	18.8	2.3
4	Pectin substances	8.4	14.1	18.3	33.8	4.2
5	Pectin	8.3	16.7	19.4	33.3	5.6
6	Protopectin	8.6	11.4	17.4	34.3	2.9
7	Vitamin C	12.8	17.9	28.2	48.7	5.1
8	Phenolic compounds	8.5	14.6	17.1	34.1	3.7
9	Cellulose	8.3	11.1	16.6	30.5	5.6

Tracing the dynamics of the decrease in pectin substances, one can see that the change in their quantity in the Khachia variety in the first variant was 7.2 % and 13.0 % in the second variant. In variety Khiakume, these indicators respectively amounted to 8.4 % according to the 1st variant and 14.1 % according to the 2nd variant. The smallest change in pectin substances was observed in variant V. So, in variant V, the change in pectin substances in the Khachia variety was 4.3 %, and in the Khiakume variety – 4.2 %. In general, during storage, the smallest quantitative changes in pectin, protopectin, and pectin were recorded in variant V. This indicator for variety Khachia fluctuated within 2.9÷5.7 %, and for variety Khiakume – within 2.9÷5.6 % (Fig. 2).

The quantitative change in pectin substances during storage of Khachia persimmon fruits according to different variants is shown in Fig. 3.

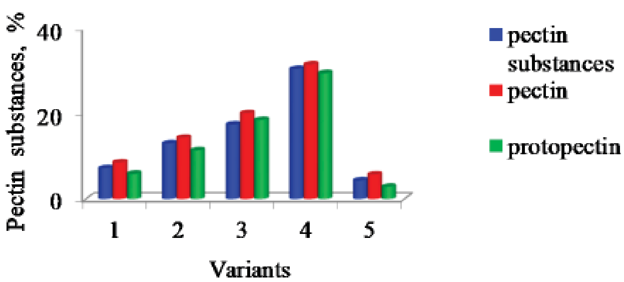

Fig. 3. Quantitative change in pectin substances during storage of Khachia persimmon fruits according to different variants

To preserve the quality of persimmon fruits for the entire period of storage in the refrigeration chamber, such conditions must be created so that the quantitative change in pectin substances is at a minimum level. Cellulose is one of the indicators of the quality of persimmon fruits. Cellulose helps keep the appearance of the product well. It is unsatisfactory that the amount of pulp changes during the storage period. Thus, its excessive quantitative reduction creates conditions for changing the appearance of persimmon fruits and its wilting. As a result of the research, it turned out that during the storage of persimmon fruits under the CGE conditions, especially according to the proposed fifth variant, the change in the amount of cellulose is quite insignificant, which does not affect the presentation of the product.

In the course of the research work, quantitative changes in vitamin C and total phenolic compounds were determined during long-term refrigerated storage of persimmon fruits in various ways.

Vitamin C, like phenolic compounds, is known to have antioxidant and antimicrobial properties. Therefore, in the refrigeration chamber where the persimmon fruits are stored, conditions must be created to prevent the breakdown of vitamin C and phenolic compounds in them.

When storing persimmon varieties in different ways, the change in vitamin C is shown in Fig. 4.

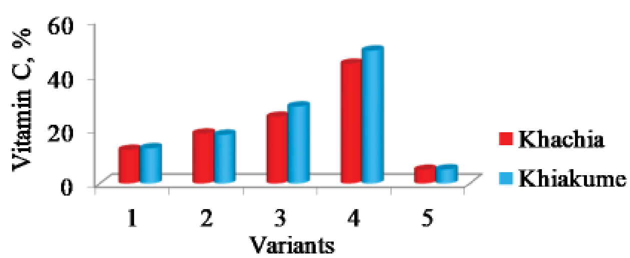

Fig. 4. Quantitative change in vitamin C during storage of persimmon varieties in different ways

Tables 7, 8, and Fig. 4 demonstrate that when storing persimmon fruits under CGE conditions, unlike other variants, vitamin C and phenolic compounds are less consumed in the process of respiration. During the storage of persimmon under CGE conditions, the decrease in the content of vitamin C was recorded within 4.9÷18.3 %, in variants III and IV within the range of 24.4÷48.7 %.

During the period of storage of both varieties in a controlled gas environment, phenolic compounds decreased by 2.4÷14.6 %. These indicators in the variant with sulfur combustion in a refrigeration chamber and storage under normal conditions decreased by 15.5÷34.1 %. In the second and third variants, microbiological diseases were found in some fruits, including a change in the presentation of the product.

Data in Tables 7, 8 showed that the smallest amount of the main quality indicators of persimmon fruits was little spent on the breathing process in the fifth variant.

In addition, individual representatives of phenolic compounds in persimmon varieties were studied by a modern method of analysis for different variants. These indicators are given in Tables 9, 10.

Table 9 demonstrates that during storage of the Khachia variety in different variants, individual representatives of phenolic compounds changed in different ways. While at the end of storage in the first variant there were two representatives of phenolic compounds out of 16, in the second variant this indicator was four, in the other variants – three. The smallest quantitative change in phenolic compounds is observed in variant V, i. e., under CGE conditions with a CO_2 composition of 3–4 % and 2–3 % O_2.

While in variant I phenolic compounds changed within 7.1–12.2 %, in variant II 8.7–11.4 %; in variant III 14.5–25.0 %; in variant IV 28.8–52.0 %, in variant V this figure was 2.6–5.4 %.

Table 9

Quantitative change in phenolic compounds during storage of Khachia persimmon variety in a refrigeration chamber according to different variants, %

No.	Indicators	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2	Under CGE conditions with the composition of gases 1–2 % CO_2; 2–3 % O_2	When burning sulfur every 10 days	Under normal conditions	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2 and the temperature in the refrigeration chamber – 2–3 °C
1	(+) catechin	7.1	8.7	15.2	38.7	2.6
2	(–) epicatechin	9.0	10.7	22.3	42.5	4.6
3	Gallic acid	9.2	10.4	25.0	44.7	4.6
4	Chlorogenic acid	7.8	9.6	21.3	35.8	4.1
5	Vanillic acid	7.2	9.4	16.6	52.0	3.8
6	Caffeic acid	8.7	11.3	17.4	28.8	3.5
7	p-coumaric acid	7.7	10.6	19.0	37.7	3.5
8	Synapic acid	8.4	11.4	19.5	35.9	3.8
9	Cinnamic acid	7.1	10.4	33.2	42.8	3.9
10	Procyanidin B_1, B_3, B_4	7.9	10.4	15.4	26.8	4.9
11	Procyanidin C_1, T_2, T_3	7.3	9.1	14.5	31.4	3.5
12	Quercetin-3-o-glucuronide	8.5	10.3	18.3	34.2	5.4
13	Quercetin-3-o-glucoside	12.2	–	–	–	–
14	Epicatechin-3-o-gallate	–	–	–	–	–
15	Myricetin 3-o-glucoside	–	–	–	–	–
16	Stilbene	10.3	–	20.7	36.8	4.6

Table 10

Quantitative change in phenolic compounds during storage of Khiakume persimmon in a refrigeration chamber according to different variants, %

No.	Indicators	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2	Under CGE conditions with the composition of gases 1–2 % CO_2; 2–3 % O_2	When burning sulfur every 10 days	Under normal conditions	Under CGE conditions with the composition of gases 3–4 % CO_2; 2–3 % O_2 and the temperature in the refrigeration chamber – 2–3 °C
1	(+) catechin	9.2	11.3	31.6	46.2	5.4
2	(–) epicatechin	10.1	12.1	21.2	44.7	7.2
3	Gallic acid	9.4	11.7	20.2	37.9	6.2
4	Chlorogenic acid	9.6	11.4	18.9	38.2	4.4
5	Vanillic acid	9.4	11.6	19.4	38.0	5.1
6	Caffeic acid	9.9	11.9	19.6	39.1	6.2
7	p-coumaric acid	9.3	12.6	26.2	45.0	5.5
8	Synapic acid	8.1	12.9	28.6	40.9	2.9
9	Cinnamic acid	8.1	11.7	20.4	31.4	4.9
10	Procyanidin B_1, B_3, B_4	9.3	11.2	15.8	22.6	5.9
11	Procyanidin C_1, T_2, T_3	10.7	10.7	21.0	22.8	6.6
12	Quercetin-3-o-glucuronide	9.6	11.5	23.3	30.1	4.7
13	Quercetin-3-o-glucoside	–	–	–	–	–
14	Epicatechin-3-o-gallate	–	12.0	–	41.9	–
15	Myricetin 3-o-glucoside	–	–	25.6	–	–
16	Stilbene	7.8	10.9	31.2	43.8	4.7

It can be said that in variant V, compared with other variants, the content of phenolic compounds during the storage period of the Khachia variety decreased slightly.

Data in Table 9 show that the main chemical indicator of persimmon fruits, which has antioxidant and antimicrobial properties (+) catechin, in variant I decreased by 7.1 %, in variant II – by 8.7 %, in variant III – by 15.2 %., in variant IV – 38.7 %, and in variant V only by 2.6 %.

In the Khachia variety, these indicators changed insignificantly in comparison with other variants in variant V. This indicator was identical to other phenolic compounds.

Table 10 demonstrates that during the storage of Khiakume persimmon, the quantitative content of individual representatives of phenolic compounds decreases.

During the storage of the Khiakume variety, the content of phenolic compounds decreased by 7.8–10.1 % in variant I, by 10.9–12.9 % in variant II, by 15.8–31.6 % in variant III, and by 22 .6–46.2 % in variant IV.

Analysis of Table 10 showed that if in variant I (–) epicatechin decreased by 10.1 %, this indicator in variant II decreased by 12.1 %, in variant III by 21.2 %, in variant IV by 44.7 %, and in variant V by 7.2 %.

In the course of the research work, it was found that not only low temperature but also the gaseous environment of the refrigeration chamber and sulfur dioxide affect the decrease in enzyme activity during storage of Khiakume persimmons. Therefore, individual representatives of phenolic compounds in the variant of storage under normal conditions are more spent on the breathing process. However, in the proposed variant V of persimmon storage, a change in the amount of phenolic compounds was recorded in the range of 2.9–7.2 %.

Comparing both varieties, we can conclude that over the entire period of storage in the Khachia variety, in comparison with Khiakume, individual representatives of phenolic compounds have changed little. While the Khachia variety in I variant (+) had 7.1 % catechin, the Khiakume variety had 9.2 %. Data in Tables demonstrate that according to the proposed storage variant, the content of (+) catechin in the Khachia variety decreased by 2.6 %, and in the Khiakume variety by 5.4 %.

During the storage period according to variant IV (+) catechin in the Khachia variety decreased by 38.7 %, and in the Khiakume variety by 46.2 %.

5. 3. Determination of natural and microbiological losses during storage of persimmon fruits and their tasting

During long-term storage of persimmon varieties in the refrigeration chamber, the loss rates were calculated. In addition, for each variant, a tasting was carried out on a 10-point system to evaluate the stored fruits. Based on these indicators, the quality of product storage and economic efficiency were determined. It is known that during the storage of vegeTables and fruits, including persimmons, natural and microbiological losses occur. When storing products, such conditions should be created so that both natural and microbiological losses are recorded at a minimum level. Therefore, in the course of the study, natural and microbiological losses were determined during storage of persimmon fruits in a refrigeration chamber for different variants.

Losses were calculated for all variants from the beginning to the end of storage. The results are given in Table 11.

Data in Table 11 show that during long-term refrigerated storage of persimmon fruits, general losses occur. These indicators vary by variant. While the total loss during storage of the Khachia variety according to variant I was 4.5 %, the microbiological loss was registered within 2.1 %, and the natural loss was 2.4 %.

Table 11

The magnitude of losses during storage of persimmon varieties according to different options, %

Persimmon varieties	Options	Loss			
		Natural losses	Microbiological losses	Total losses	Tasting, in points
Khachia	Variant I	2.4	2.1	4.5	8.8
	Variant II	3.5	3.2	6.7	8.5
	Variant III	4.6	5.8	10.4	8.0
	Variant IV	7.3	9.1	16.4	6.8
	Variant V	1.6	–	1.6	9.8
Khiakume	Variant I	2.7	2.1	4.8	8.6
	Variant II	3.7	3.4	7.1	8.3
	Variant III	4.8	6.4	11.2	7.8
	Variant IV	7.5	9.3	16.8	6.5
	Variant V	1.8	–	1.8	9.6

These indicators in variants II, III, and IV were higher. The smallest total losses were observed in variant V, i.e., when stored in a refrigeration chamber in CGE with a gas composition of 3–4 % CO_2, 2–3 % O_2 and a temperature of – 2...–3 °C. In this variant, in comparison with others, no microbiological losses were recorded in the refrigeration chamber during the observation period.

Table 11 demonstrates that while in variant I the total loss was 4.5 %, in variant II this figure was 6.7 %, in variant III – 10.4 %, in variant IV – 16.4 %, and in variant V – 1.6 %. The change in natural and microbiological losses in the refrigerating chamber is largely influenced by the gas mixture and temperature.

So, when storing persimmon fruits in a refrigeration chamber under normal conditions and when burning sulfur every 10 days, the total loss ranged from 10.4–16.4 %, and in variants I and II, i.e., when stored under CGE conditions – within 4.5–6.7 %. This indicator was identical with microbiological losses.

When storing persimmon fruits in a controlled gas environment, the microbiological loss was recorded in the range of 2.1–3.2 %, while in variants III–IV this figure was 5.8–9.1 %. When stored under normal refrigerated conditions, the Khachia variety had a greater microbiological and natural loss than Khiakume.

The natural, microbiological, and total losses determined during storage of the Khachia variety for different variants were almost identical to the Khiakume variety.

Compared to the Khiakume variety, the Khachia variety had a relatively lower storage loss. While the total loss during storage according to variant I was exactly 4.8 % for the Khiakume variety, for the Khachia variety this figure was 4.5 %. It has been established that during storage of the Khiakume variety according to the fifth variant, the value of natural, microbiological, and general losses is less than 1.8 % compared to other variants.

The total loss during storage of the Khiakume variety according to variant V was 1.8 %, while for the Khachia variety this figure was 1.6 %.

Microbiological losses were recorded in all variants, except for variant V. The greatest microbiological losses occurred during the storage of persimmon fruits in a refrigeration chamber under normal conditions – 9.1–9.3 %. The absence of microbiological losses in variant V can be explained by keeping the product at a temperature of –2–3 °C under conditions of high CO_2 content. Therefore, compared with other variants, the storage quality of the fifth variant was highly appreciated.

As a result of the tasting, the persimmon stored according to variant I was rated 8.6–8.8 points, according to variant II – 8.5–8.3 points, according to variant III – 7.8–8 points, according to variant IV – 6.5–6 8 points, and according to variant V– 9.6–9.8 points.

5. 4. Improving the storage regime of persimmon fruits

Persimmon fruits are rich in nutrients, including simple sugars, phenolic compounds, vitamins, minerals, and are suiTable for long-term storage in a refrigeration chamber. During storage of fruits, the decay of essential nutrients occurs due to increased activity of enzymes.

The analysis of our studies shows that all the studied enzymes are more active in the Khachia variety than in the Khiakume variety.

The composition of persimmon fruits is rich in simple sugars necessary for the human body, including glucose and fructose, as well as other nutritional components.

Studies have shown that there are representatives of phenolic compounds that are found only in the Khachia variety, and vice versa. While myricetin-3-o-glucoside and stilbene were present in Khachia, these compounds were not registered in Khiakume. Quercetin-3-o-galactoside was found only in the Khiakume variety. In addition, individual representatives of phenolic compounds in the Khachia variety were quantitatively more pronounced compared to the Khiakume variety.

The fruits of both varieties of persimmon are rich in minerals, especially iodine. As a result of the analysis, it turned out that persimmon fruits contain more K, Na, Cu, Mg, Zn, Fe, J. An overestimated amount of iodine was recorded in the Khachia variety than in the Khiakume variety.

Persimmon fruits are also rich in cellulose. As persimmons ripen, the cellulose content in it gradually decreases and turns into other components, mainly sugar.

During the period of storage of persimmon, the determination of the activity of the peroxidase enzyme in variants I, II, III decreased, and in version IV, on the contrary, it increased by 14.3 %. The activity of the catalase enzyme tended to gradually decrease during the storage period of the Khachia variety for the four studied variants.

When stored under CGE conditions, persimmon fruits of the Khachia variety in a refrigeration chamber, compared with other variants, the activity of the enzyme is significantly reduced. This is mainly due to the fact that carbon dioxide in the refrigeration chamber contributes to a decrease in enzyme activity.

During the entire storage period, the activation of enzymes is explained by the increased temperature inside the fruit, which reaches +3 °C...+4 °C, sometimes even +5 °C. Therefore, the regulation of enzyme activity is highly dependent on the ambient temperature. These indicators in variants II, III, and IV were higher. The smallest total losses were observed in variant V.

Microbiological losses were recorded in all variants, except for variant V.

It was found that when storing persimmon fruits under CGE conditions, compared with other variants, not only phenolic compounds but also other food components are consumed for the respiration process. Therefore, in order to provide people with high-quality persimmon fruits for a long time, it is recommended to store them in a refrigeration chamber under CGE conditions with a CO_2 gas content of 3–4 %, O_2 2–3 %, a temperature in the refrigerator chamber of 2–3 °C, and a relative humidity of 90–95 %. The persimmon fruits stored according to this variant did not lose their original and markeTable appearance. Compared to other variants, in the fifth, recommended variant, the natural losses were significantly less, and the tasting score was higher.

6. Discussion of experimental results of studying the possibility of storing persimmon fruits in the refrigeration chamber

When storing plant products, various biochemical, physiological, and microbiological processes occur. Storage factors are environmental controls that reduce storage loss or extend the potential shelf life. Maintaining storage conditions within optimal limits is the main technological challenge in storage. Therefore, healthy specimens with a high content of phenolic compounds are selected for storage, as they are natural antioxidants and antioxidants.

Analysis of studies of qualitative indicators of persimmon varieties shows that the metabolic process proceeds with the participation of enzymes. Photosynthesis, respiration, assimilation of nutrients, even the biosynthesis of organic and inorganic substances in living cells occurs under the action of enzymes. The quality of long-term storage of persimmon fruits in different ways is closely related to changes in the activity of oxidative enzymes. The highest activity of the peroxidase enzyme was recorded in fully ripened persimmons, followed by the enzymes o-diphenol oxidase and ascorbate oxidase. The lowest activity was noted in both persimmon varieties in the catalase enzyme. The significant reduced activity of all the studied enzymes in the Khiakume variety is explained by the fact that the fruits of this variety are rich in antioxidant substances, mainly phenolic compounds.

From the results of a study of the biochemical parameters of persimmon fruits, it became known that it is rich in nutrients and total sugar. Glucose and fructose form the basis of total sugar. More than 90 % of the total sugar in persimmon fruits is glucose and fructose. In persimmon fruits, these simple sugars are in a free state, and this is the main indicator of the nutritional value of persimmon fruits. There was no difference in total sugar content between the two varieties.

From the data given in Table 2 and Fig. 1, 2, it is clear that the content of glucose and fructose is higher in the composition of persimmon fruits. Persimmon fruits contain more fructose than glucose. While persimmon fruits contained glucose in the range of 8.1÷7.6 g/100 g, the amount of fructose was 8.8÷8.5 g/100 g. The content of more fructose in persimmon fruits has a positive effect since fructose is twice as sweet as glucose. Therefore, the fact that fully ripened persimmon fruits have a sweet taste is due to the fact that they contain more fructose.

Analysis of data in Table 2 shows that the Khiakume persimmon variety is relatively rich in pectin than the Khachia variety. While the variety Khiakume contained 0.71 g/100 g of pectin, for the variety Khachia this figure was 0.69 g/100 g. The content of pectin and protopectin in both varieties was almost the same.

One of the main quality indicators of persimmon fruits is their richness in vitamins. In ongoing studies, quantitative changes in vitamin C in fully ripe persimmon fruits were studied. It is known that vitamin C is important for a healthy and long human life, strengthens the immune system, and is a natural antioxidant. The content of vitamin C in the Khachia variety was much higher than that in the Khiakume variety.

The second place among the biochemical indicators of persimmon is occupied by phenolic compounds. As a result of the analyses, it was found that there was no greater difference in the amount of phenolic compounds in both varieties. In the Khachia variety, the content of phenolic compounds was 0.84 g/100 g, and in the Khiakume variety it was 0.82 g/100 g.

Persimmon fruits are also rich in pectin and cellulose. As the persimmon ripens, the content of pectin and cellulose in it gradually decreases and turns into other components. Pectins and cellulose are less in juice and pulp and more in persimmon peel.

Persimmon is a natural medicine used in the treatment and prevention of thyroid disorders. The analysis of the data proved that the fruits of the persimmon variety Khachia contain iodine in the amount of 0.250 mcg/100 g, and in the variety Khiakume 0.220 mcg/100 g.

The figures given in Table 3 indicate that the amount of mineral substances in the Khachia variety is higher than that in the Khiakume variety. With a lack of minerals in the human body, the process of exchanging some vital proteins, enzymes, hormones, vitamins, and others is disrupted. This is the cause of many forms of disease. Therefore, the daily diet of a person should contain foods rich in minerals.

From the results of studies of phenolic compounds in persimmon fruits, about 16 of their representatives were found. The molecular weights of individual representatives of phenolic compounds were determined. It turned out that the molecular weight of phenolic compounds varies in different ways. In the Khachia variety, 15 representatives of phenolic compounds were found, and in the Khiakume variety, 14 representatives. Data in Table 4 show that persimmon fruits are rich in catechins, gallic, chlorogenic, caffeic, vanillic, and synapic acids.

However, such phenolic compounds were found, which were more in the Khiakume variety and less in the Khachia variety. Vanillin and caffeic acid in the Khiakume variety were in the amount of 434.9–463.2 mg/kg, and in the Khiakume variety, respectively, 121.4 mg/kg and 326.4 mg/kg. It is important to note that myricetin-3-o-glucoside and stilbene were present only in the Khachia variety, while quercetin-3-o-galactoside was found only in the Khiakume variety.

A comparative analysis of the results of studies carried out on variants I, II, III, and IV shows that the activity of enzymes, with the exception of variant IV, gradually decreases. While during storage of the Khiakume variety in variant I, the activity of the ascorbate oxidase enzyme decreased by 76.4 %, in variant II this indicator decreased by 70.9 %, and in variant III – by 61.8 %.

Many studies consider the development of improved storage methods for products. In vacuum storage, the use of dryers, long drying time of the material, high metal consumption of the installation, complexity of setup and operation require the development of a simpler and cheaper storage method [27]. The method of storing fruits in a controlled gas environment does not require additional costs, and most importantly, the original properties and presentation of the fruits are preserved.

An analysis of the quality indicators of persimmon fruits of the Khachia variety during refrigerated storage showed that the activity of the peroxidase enzyme in variants I, II, III decreased, and in version IV, on the contrary, increased by 14.3 %. The activity of the catalase enzyme tended to gradually decrease during the storage period of the Khachia variety for the four studied variants. During refrigerated storage of the Khiakume variety, in variant I, the activity of the ascorbate oxidase enzyme decreased by 76.4 %, in variant II it decreased by 70.9 %, and in variant III, by 61.8 %. In variant IV, the activity of the ascorbate oxidase enzyme increased by 23.6 %. Data in Table 6 and Fig. 5 show that the activity of the enzyme o-diphenol oxidase decreases during storage of the Khiakume variety under normal conditions, while the activity of other enzymes – ascorbate oxidase, peroxidase and catalase increases. When storing fruits, it is important to ensure that moisture evaporation does not adversely affect the quality and organoleptic characteristics of raw materials [28].

As a result of the study, it was found that during the storage period, the activity of all enzymes, except for ascorbate oxidase, completely stopped (except for the catalase enzyme in the Khachia variety). During long-term storage of the Khachia variety in a refrigeration chamber, the activity of the enzyme ascorbate oxidase decreased by 94 %, o-diphenol oxidase and peroxidase decreased by 100 %, catalase by 95.5 %. When the activity of ascorbate oxidase decreased by 94.5 % in persimmon fruits of the Khiakume variety, the activity of other enzymes was completely inhibited. A decrease in the activity of o-diphenol oxidase contributes to the preservation of phenolic compounds, especially polyphenols, in fruits [29].

With improper storage of fruits and vegetables, many quality indicators are lost [30].

Organoleptic indicators, including appearance, nutritional value, and quality indicators of both varieties of persimmon at the end of storage have not changed. The recommended method is to store persimmons in the refrigerator for more than 5 months. The quality of persimmon storage according to this variant depends on the gaseous environment of the refrigerating chamber and the correct regulation of air humidity in it. A further decrease in the activity of enzymes during storage in this environment significantly prevents the breakdown of the nutritional components that make up the persimmon fruits.

Analysis of data in Table 7 and Fig. 2 shows that when storing persimmon fruits in a refrigeration chamber by burning sulfur every ten days, the total sugar changes in different ways. The total sugar in the Khachia variety decreased by 11.5 %, including glucose by 12.3 % and fructose by 12.5 %. A significant decrease in these indicators was recorded during storage of persimmon fruits in a refrigeration chamber under normal conditions – 17.1÷22.1 %.

To preserve the quality of persimmon fruits over the entire period of storage in the refrigeration chamber, such conditions must be created so that the quantitative change in pectin substances is at a minimum level. After all, the breakdown of pectin into polygalacturonic acid and methyl alcohol destroys the cellular structure of the fetus, worsens the appearance and taste, and also contributes to an increase in natural and microbiological losses.

Comparative analysis of Tables 9, 10 shows that the main chemical index of persimmon fruit, which has antioxidant and antimicrobial properties (+) catechin in the Khachia variety was 2.6 %, in the Khiakume variety 5.4 %. (–) Epicatechin in the Khachia variety decreased by 7.2 %, in the Khiakume variety by 4.6 %.

With long-term refrigerated storage of persimmon fruits, general losses occur. Data in Table 11 make it possible to conclude that the loss rates differ by variants. While the total loss during storage of the Khachia variety according to variant I was 4.5 %, the microbiological loss was recorded within 2.1 %, and the natural loss was 2.4 %. In variant I, the Khiakume variety was 4.8 %, while the microbiological loss was recorded within 2.1 %, and the natural loss was 2.7 %.

A common method of storing raw materials in cardboard boxes and paper bags promotes the development of microorganisms [31]. When fruits are stored in a controlled gas environment, microbiological spoilage is not observed. Microbiological losses were recorded in all variants, except for variant V. The greatest microbiological losses occurred during the storage of persimmon fruits in a refrigeration chamber under normal conditions – 9.1–9.3 %. The absence of microbiological losses in variant V can be explained by keeping the product at a temperature of –2–3 °C under conditions of high CO_2 content.

When tasting, the persimmon stored according to variant I was rated 8.6–8.8 points, according to variant II – 8.5–8.3 points, according to variant III – 7.8–8 points, according to variant IV – 6.5–6.8 points, and according to variant V – 9.6–9.8 points.

While when storing fruits due attention is not paid to ripeness, varietal characteristics and innovative storage techniques [32], then it is impossible to achieve the desired result.

A common method of storing fruits and berries is freezing. Freezing is accompanied by a deep decrease in the temperature of the fruit and the transformation of moisture into ice, i. e., dehydration. The formation of ice crystals causes changes in the tissue structure of the product, the degree of which depends on the freezing rate [33]. With slow freezing of fruits at relatively high temperatures, ice crystals are formed mainly in the intercellular spaces. In the middle of the cells, where the juice concentration is higher, ice forms more slowly. The formation of ice crystals and the associated increase in the concentration of juice in the intercellular spaces leads to an increase in osmotic pressure. Water from the cells passes into the intercellular space, where it freezes at the edges of previously formed crystals. In this case, the cells are dehydrated, and large crystals are formed in the intercellular spaces, which are unevenly distributed in the tissues. Crystals put pressure on neighboring cells and cause damage to cell membranes and their death [34]. Therefore, considering that when the fruits are thawed, the moisture formed does not have time to be absorbed, the juice flows out, the product loses its natural properties: it changes its consistency, becomes watery and quickly becomes infected with microbes, it is important to develop a more optimal storage regime.

The development of new technological regimes for the storage of fruits and fruits rich in nutrients will improve existing storage technologies and provide people with environmentally friendly products throughout the year.

Fresh persimmon fruits with high nutritional value are consumed only for 1–2 months. Most remain at the top of the tree, deteriorate, and are thrown away as waste. Therefore, in the studies of some authors, to ensure a healthy lifestyle of people, the methods of storage and long-term use of this valuable food product for a long time without changing quality indicators do not occupy a special place. Whereas in this paper, changes in the quality indicators of persimmon varieties during long-term refrigerated storage, depending on the dynamics of enzyme activity, are analyzed.

The results of our study of the activity of enzymes and their influence on the change in the quality indicators of persimmon make it possible to determine the optimal mode of storage in the refrigeration chamber using CGE and use it as a food product throughout the year.

The study revealed limitations associated with the fact that during storage of persimmon varieties under normal conditions, the percentage of biochemical parameters decreases.

In addition, with different storage techniques, due to a small decrease in the activity of enzymes, the nutritional value of the finished product decreases. An increase in the activity of ascobate oxidase contributes to a decrease in vitamin C in wine. The activity of peroxidase leads to the breakdown of aromatic amines. O-diphenol oxidase, when activated, breaks down phenolic compounds. With different storage methods, pectin is split into methyl alcohol and polygalacturonic acid. Ultimately, the persimmon wilts, the cellular structure is destroyed, and the taste and organoleptic properties of the fruit deteriorate. When storing fruits, it is important to regulate the activity of enzymes to maintain the presentation, as well as enrich the finished product with nutrients.

It should be noted that storage under normal conditions assumes a normal air environment with a normal content of oxygen (21 %), carbon dioxide, and other gases in the atmosphere. But the method of storing fruits based on the creation of an artificial or regulated (controlled) gas environment is becoming more widespread. In addition, the storage process is largely affected by temperature, humidity, and the composition of the gaseous medium. The correct choice and successful practical application of the mode of storage of fruits in the future will be an incentive to improve the relevant technological parameters of storage in order to achieve greater preservation of useful substances.

A high-quality, environmentally friendly product is the most strategic indicator. The process parameters must be improved to use the optimum gas composition to limit degradation and reproduction of biologically inactive components. This diversity will further expand the methods of storage of fruits and vegetables.

The development of new technological methods of storage with the use of CGS will make it possible to modernize existing technologies for providing people with environmentally friendly products.

7. Conclusions

1. It has been established that it is advisable to use ripe persimmon fruits for storage in a refrigeration chamber. To preserve the quality indicators of persimmon fruits, it

is important to pay special attention to changes in enzyme activity. All the studied enzymes were more active in the Khachia variety than in the Khiakume variety. For example, while the activity of the peroxidase enzyme was 2.1 μmol/sec in the Khachia variety, this figure in the Khiakume variety was 1.98 μmol/sec. Accordingly, ascorbate oxidase activity was 0.66 μmol/sec and 0.55 μmol/sec, 0.74 μmol/sec and 0.72 μmol/sec for o-diphenol oxidase, and 0.44 μmol/sec and 0.36 μmol/sec for catalase. There was no significant difference in total sugar content between the two varieties. While the mature Khachia variety had a total sugar of 20.8 g/100 g, in Khiakume this figure was 20.5 g/100 g. The Khiakume persimmon variety is relatively rich in pectin than the Khachia variety. While the Khiakume variety contained 0.71 g/100 g of pectin, in the Khachia variety this figure was 0.69 g/100 g. The content of pectin and protopectin in both varieties was almost the same. While the amount of total pectin in the Khachia and Khiakume varieties was 0.35–0.36 g/100 g, the protopectin content changed accordingly within the range of 0.34 to 0.35 g/100 g. Studies showed that the Khiakume variety is rich in vitamin C. While the Khachia variety contained 0.082 g/100 g of vitamin C, in the Khiakume variety this figure was 0.078 g/100 g.

The rich mineral composition of persimmon allows us to conclude that the amount of potassium in the Khachia variety is 134.2 mg/100 g, in the Khiakume variety – 125.4 mg/100 g. The amount of Mg in the Khachia variety was 4.18 mg/100 g, and in the Khiakume variety, 3.85 mg/100 g. In the Khachia variety, the Na content was 8.4 mg/100 g, and in the Khiakume variety, 7.2 mg/100 g.

2. It has been established that the activity of the studied enzymes in variants I, II, III, IV is not completely inhibited during storage of Khachia persimmon variety in a refrigeration chamber. When storing persimmon fruits in the refrigeration chamber under normal conditions, the activity of some enzymes not only did not decrease but exceeded the original version. In the Khachia variety, the enzyme o-diphenol oxidase decreased by 86.5 % by the end of storage according to variant I, by 73.0 % in the second variant, by 64.9 % in the III variant, and by 29.7 % in the variant V. However, the activity of the peroxidase enzyme in variants I, II, III decreased, and in the IV version, on the contrary, it increased by 14.3 %. The activity of the catalase enzyme of the Khachia variety gradually decreased during the storage period for all four studied variants. During storage of the variety Khiakume according to variant I, the activity of the ascorbate oxidase enzyme decreased by 76.4 %, in variant II it decreased by 70.9 %, and in variant III – by 61.8 %. During storage of the Khiakume variety according to Variant V, the activity of the ascorbate oxidase enzyme increased by 23.6 %, the activity of the o-diphenol oxidase enzyme decreased. However, the activity of other enzymes – peroxidase and catalase – increased.

During the period of storage of persimmon according to the fifth variant, the activity of all enzymes, except for ascorbate oxidase, completely stopped (except for the catalase enzyme in the Khachia variety). With long-term storage of the Khachia variety in a refrigeration chamber, the activity of the ascorbate oxidase enzyme decreased by 94 %, and the activity of o-diphenol oxidase and peroxidase decreased by 100 %, and that of catalase by 95.5 %. Ascorbate oxidase activity decreased by 94.5 % in persimmon fruits of the Khiakume variety, and the activity of other enzymes was completely inhibited.

During the storage of both varieties of persimmons in the refrigeration chamber under the conditions of CGE, total sugars, including glucose and fructose, were spent less on the respiration process. When storing persimmon fruits in a refrigeration chamber by burning sulfur every ten days, the total sugar in the Khachia variety decreased by 11.5 %, including glucose by 12.3 %, and fructose by 12.5 %. A significant decrease in these indicators during storage of persimmon fruits in a refrigerator under normal conditions was in the range of 17.1÷22.1 %. The smallest change in total sugar, including glucose and fructose, was recorded in the proposed variant V. The smallest change in pectin substances was observed in variant V: in the Khachia variety it was 4.3 %, and in the Khiakume variety it was 4.2 %. In general, during storage, the smallest quantitative changes in pectin substances, protopectin, and pectin were recorded in variant V. This indicator for the Khachia variety ranged from 2.9÷5.7 %, and for the Khiakume variety – within the range of 2.9÷5.6 %.

When storing persimmon fruits under CGE conditions, unlike other variants, vitamin C and phenolic compounds were less spent on the respiration process. During the storage of persimmon under CGE conditions, the decrease in the content of vitamin C was recorded within 4.9÷18.3 %, in variants III and IV within the range of 24.4÷48.7 %.

During storage of the Khachia variety in different variants, individual representatives of phenolic compounds changed in different ways. At the end of storage, according to the first variant, two representatives of phenolic compounds out of 16 remained, in the second variant – four, in the remaining variants – three. The smallest quantitative change in phenolic compounds was observed in variant V, i. e., under CGE conditions with a composition of 3–4 % CO_2 and 2–3 % O_2. During the storage of the Khiakume variety, the content of phenolic compounds decreased by 7.8–10.1 % in variant I, by 10.9–12.9 % in variant II, by 15.8–31.6 % in variant III and by 22 .6–46.2 % in variant V.

Studies have shown that the presence of antioxidant and astringent properties in persimmon is associated with representatives of polymeric phenolic compounds – hydrolyzable and non-hydrolyzable tannins, catechins, and some bioflavonoids from flavonoids.

3. When storing products, such conditions must be created so that both natural and microbiological losses are at a minimum level. During long-term refrigerated storage of persimmon fruits, the total losses differed according to the variants. These indicators in variants II, III, and IV were higher. The smallest total losses were observed in variant V. When storing persimmon fruits in a refrigeration chamber under normal conditions and when burning sulfur every 10 days, the total loss ranged from 10.4–16.4 %, and in variants I and II, i. e., when stored under CGE conditions, within 4.5–6.7 %. This indicator was identical with microbiological losses.

Compared to the Khiakume variety, the Khachia variety had a relatively lower storage loss. While the total loss during storage in variant I was 4.8 % for the Khiakume variety, for the Khachia variety this figure was 4.5 %. It has been established that during storage of the Khiakume variety according to the fifth variant, the value of natural, microbiological, and general losses is less than 1.8 %. At the end of storage, a tasting of persimmon fruits was carried out. As a result of the tasting, the persimmon stored according to variant I was rated 8.6–8.8 points, according to variant II – 8.5–8.3 points, according to variant III –

7.8–8 points, according to variant IV – 6.5–6.8 points, and according to variant V – 9.6–9.8 points.

4. To preserve the quality of persimmon fruits for the entire period of storage in the refrigeration chamber, such conditions must be created so that the quantitative change in nutrients is at a minimum level. To achieve this result, it is important that the activity of oxidative enzymes decreases or passes into an inhibitory state. Therefore, it is recommended to store persimmon fruits for a long time in a refrigeration chamber under CGE conditions with a gas content of 3–4 % CO_2, 2–3 % O_2 with a temperature in the refrigeration chamber of –2...–3 °C and a relative humidity of 90–95 %.

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

All data are available in the main text of the manuscript.

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