Japan Bilingual Publishing Co.

Food and Drug Safety
https://ojs.bilpub.com/index.php/fds

ARTICLE

The Nature of Respiration During the Storage of Grapes of Different Varieties

Rauf Asadullayev [*] **, *Aida Najafova*** **, *Vugar Salimov***

Scientific Research Institute for Viticulture and Wine-making Under the Ministry of Agriculture of the Azerbaijan Republic, Baku AZ-1000, Azerbaijan

ABSTRACT

Losses of grapes during the period of cold storage consist of microbiological and physiological spoilage, water evaporation and the consumption of organic substances for respiration. The main objective of this experimental study was to determine the influence of the character of respiration of grape berries during storage on the storability of the variety. During the research, we determined the yield of grapes that met quality standards through commodity analysis. The amount of weight loss of grapes during storage was determined by weighing. Statistical analyses were carried out using a one-way ANOVA calculator and Tukey's HSD test. The alcohol content in grapes was determined using the dichromate-iodometric method, and the respiration rate was determined by measuring carbon dioxide released by berries. We found that the amount of natural weight loss and the yield of standard products after the storage period differed sharply depending on the grape variety. The varieties with better shelf life (Agadai and Gara Shany) were distinguished by more uniform respiration during storage, and their climacteric peak occurred significantly later than that of the varieties with less shelf life (Ag Shany and Sarygila). Reaching the peak can serve as a signal for producers to swiftly sell the stored grapes. Thus, the intensity of grape berry respiration can serve as an indicator of the shelf life of the variety.

Keywords: Table Grapes; Long-Term Storage; Respiration; Losses

*CORRESPONDING AUTHOR:
Rauf Asadullayev, Scientific Research Institute for Viticulture and Wine-making Under the Ministry of Agriculture of the Azerbaijan Republic, Baku AZ-1000, Azerbaijan; Email: asadullayevrauf@gmail.com

ARTICLE INFO
Received:13 May 2025 | Revised: Day 27 June 2025 | Accepted: 11 July 2025 | Published Online:21 July 2025
DOI: https://doi.org/10.55121/fds.v2i2.567

CITATION
Asadullayev, R., Najafova, A., Salimov, V., 2025. The Nature of Respiration During the Storage of Grapes of Different Varieties. Food and Drug Safety. 2(2): 45–55. DOI: https://doi.org/10.55121/fds.v2i2.567

1. Introduction

Grapes are one of the oldest plants growing on Earth; their age is estimated at about 100 million years. People began cultivating grapes in the Bronze Age. One kilogram of grapes contains 150–200 g or more of sugar in the form of glucose and fructose, 0.5–1.4% of organic acids (tartaric, malic, etc.), vitamins A (carotene), B3 (riboflavin), C (ascorbic acid), adermin and P (citrine), 0.3–1.5% of minerals (phosphorus, potassium, iron, calcium, etc.), 0.1–0.9% of proteins, 0.3–1.0% or more of pectin substances. Successful development of table viticulture largely depends on the correct selection and placement of varieties, taking into account natural conditions and agrobiological features of the area, as well as the commercial appearance and chemical and technological value of berries, their keeping quality and transportability, and the effective use of the harvest for its intended purpose [1–3].

From the point of view of growing varieties for various purposes, Azerbaijan is one of the most promising regions in the world. Characterising the modern assortment of grapes in Azerbaijan, it is possible to note its confinement to separate zones, as well as the presence of varieties of different ecological-geographical groups. In terms of the assortment of grapes, Azerbaijan is at the junction of two influences. We know that the assortment of grapes in Georgia (especially in the western part of the country) is rich in strongly pubescent forms, belonging to the ecological-geographical group of the Black Sea basin (convar pontica Negr.), while in the assortment of the countries of Central Asia, bare-leaved forms, related to the eastern ecological-geographical group (convar orientalis Negr.), predominate. The assortment of Azerbaijan was most strongly influenced by the eastern group, about 80% of all varieties. Many varieties (Ag Geibandam, Gara Pishras, Gara Shany, etc.) combine the characteristics of the eastern group (size of bunches and berries) and varieties of the Black Sea basin (felt pubescence of leaves). This undoubtedly indicates the hybrid nature of such varieties. As a result of many years of natural and artificial selection, a rich fund of indigenous grape varieties (more than 400) for various economic purposes has been created in Azerbaijan [1,4,5].

The relief of our country is highly diverse, ranging from lowlands 28 meters below sea level to mountains exceeding 4,400 meters. Altitude significantly influences the selection of grape varieties, as higher altitudes extend the vegetation period required for the full ripening of certain varieties due to reduced heat availability. Climatic factors, such as the sum of active temperatures and consequently the conditions needed for the ripening of different grape groups, also vary with altitude. The altitude above sea level also affects the humidity of the area: in the South Caucasus, the amount of precipitation increases with increasing altitude by approximately 20% per 100 m. In this regard, when assessing heat resources and humidity in mountainous areas, it is necessary to make appropriate adjustments. The further south the territory, the higher the grapes can be grown [1,6–8].

The period of consumption of fresh grapes with high nutritional and dietary qualities is limited by the seasonality of this plant and lasts 3 to 4 months. The main way to extend the consumption of fresh grapes, along with the correct selection of varieties by region, is to organise their long-term storage. The main goal of long-term storage is to maintain stable initial characteristics of grapes and minimise losses. The ability of grapes to be stored for a long time, meaning the preservation of their appearance and taste for several months without significant losses in weight and quality, depends on various factors. Individual characteristics of the variety are the main indicator determining the long-term storage of grapes; not all of the highest quality grape varieties are suitable for storage and transportation, mainly due to the thin skin of the berry [1,5,9].

The degree of ripeness of the grapes has a great influence on their keeping quality. Bunches of keeping quality varieties, whose berries are fully ripe and have accumulated a sufficient amount of sugar, are better preserved. Grapes that are not fully ripened lose moisture more intensively, wither, and are damaged by microorganisms more quickly. Biochemical processes include those caused by the action of the product`s enzymes. The activity of a particular process depends on the nature of the product, the characteristics of metabolism, and storage conditions. The processes that occur in the bunches after harvesting are mainly a continuation of the processes that occurred in them when they were on the plant. This explains the extremely large influence of growing conditions and the time of harvesting on the keeping quality of grapes [10–13].

The ability of varieties to be stored for a long time depends on their ripening period. Early ripening varieties are the least suitable for storage, and late and very late ripening varieties are the most suitable. In addition to the difference in anatomical structure, there are also differences in the metabolism of tissue cells. Since early-ripening varieties ripen at high temperatures, the metabolism in the tissues adapts to these conditions and is more intensive than in late-ripening varieties, which ripen when the weather is much cooler. It should be borne in mind that the early ripening characteristic of a variety has nothing to do with a certain delay in the ripening of introduced varieties in a new location. For a recently introduced variety, in unfavourable conditions (a relatively short vegetation period, an insufficient sum of active temperatures, rainy weather in the autumn period), there is not enough time for the crop to fully ripen, and the variety loses the valuable qualities it exhibited in its original growing region [12–14].

The shelf life of fresh grapes, which have valuable nutritional and dietary properties, is limited by the season of their ripening. The main purpose of prolonging the shelf life of fresh grapes is to select varieties with various ripening periods and plant them in areas with diverse climatic conditions. In addition to the correct placement of specific varieties in cultivation areas, it is necessary to organise long-term refrigerated storage of grapes. The main purpose of cold storage is to minimise losses and preserve the original quality of the berries. The shelf life of grapes is the ability to maintain their appearance and taste for several months without significant weight and quality losses under the influence of various factors. In addition to the correct selection of grape varieties of different ripening periods for cultivation, another way to extend the shelf life of grapes is to organise long-term storage. To complete this task successfully, it is important to study thoroughly the processes occurring in berries during the storage period [13,15,16].

During long-term storage of grapes, the quality is affected by various conditions inside the storage chambers—temperature, relative humidity and air movement, and in the case of a controlled gas environment, its composition. Each of these factors has a specific effect on the life processes occurring in the berries and determines the nature and extent of possible product losses. Regulation of these indicators, both in combination and separately, allows us to determine the optimal method of storing bunches. Optimally selected conditions and the chosen storage method allow us to maximise the potential for preserving varieties. For such a delicate product as grapes, the selection of a temperature regime is of great practical interest. In general, many authors agree that the optimal temperature in the chamber where the grapes are stored is from 0 to –1 °C, with an air humidity of 92–94%. However, these indicators may change depending on what diseases the grapes are susceptible to in the place of growth. Lowering the temperature in the chamber to –2 ° C is not recommended, since in some varieties this causes physiological disorders manifested in a change in the colour and consistency of the berries. The main influence on the results of storage is exerted by the intensity of berry respiration, which determines the rate of ageing of bunches. It has been established that low temperatures suppress the intensity of physiological processes, including respiration [13,15,17–19].

The losses of grapes during the storage period comprise microbiologic and physiologic decays, evaporation of water and the expenditure of organic substances for respiration. Respiration is among the important processes ongoing in grape berries during the storage period, staying at the centre of metabolism and determining its functioning [19–21]. Losses caused by the spoilage of grapes are a serious problem for producers and traders both before and after harvest. During the period of storage in refrigerators, the main pathogens are microorganisms that are representatives of epiphytic microflora. Microbiological spoilage caused by fungi and bacteria constitutes a significant part of grape losses during long-term storage. According to research, losses and waste at various stages can reach 53% of the produced grapes. After harvesting, dissimilation (respiration) processes continue, and the transpiration function is preserved. The intensity of these processes depends on the grape variety, growing region, agricultural technology, ripening stage and storage technology. As the intensity of biochemical processes increases, the course of deep and irreversible changes that indicate ageing of the berries accelerates. The shelf life decreases, and the appearance of the bunches deteriorates. They gradually soften, lose their taste and nutritional value, and various microorganisms begin to develop on them. The properties of the berry skin—thickness, presence of a wax layer - are of great importance in the resistance of grapes to microbial damage. When the integrity of the shell is compromised, the path opens for microbes to enter the deep layers of tissue [22–25].

During the storage period of grapes, the main source of respiration is carbohydrates. Oxygen entering the berries oxidises the part of the sugar into CO_2 and water, with the extraction of heat. It should be noted that while the temperature inside the storage camera is regulated through ventilation, the expenditure of dry stuff may increase because of higher temperatures caused by respiration, which leads to the growth of microorganisms and the decay of yeast [23,25,26].

As grapes develop during storage, the coordination of individual links in the respiration process is disrupted, which allows oxidation to stop at some intermediate stage. In this case, anaerobic respiration occurs with the accumulation of under-oxidised products (ethyl alcohol, acetic aldehyde, etc.), which ultimately leads to the appearance of visible signs of physiological metabolic disorder, such as darkening, spots, and necrosis. They are especially pronounced during the progressive ageing of organs and tissues, when resistance to such disorders is lost [13,15,27–29].

Under conditions of oxygen deficiency, anaerobic respiration leads to the accumulation of ethanol and acetaldehyde in berry cells, which has an intoxicating effect on plant tissues. Due to the plant's use in the synthesis of organic compounds, alcohol and acetaldehyde cannot reach a dangerous level during maturation. However, during the storage period, when the synthesis process is almost completely stopped, there exists a real threat of overconcentration of volatile products of anaerobic respiration. The concentration of these toxic substances leads to the rapid destruction of cells, which is evident in the fact that the flesh of the berries acquires a brown tint and the taste becomes "cooked". An increase in ambient temperature, which speeds up breathing, leads to a sharp rise in the amount of heat released by the bunches [15,24,29].

2. Materials and Methods

2.1. Location and Environmental Conditions

The research was conducted in the Ampelographic Collection of the Azerbaijan Research Institute of Viticulture and Winemaking, located on the territory of the Absheron Peninsula. The climate of the peninsula is dry subtropical. Summer is dry and hot. High summer temperatures are softened by strong northern winds. Winter is relatively moderate; the weather is often cloudy, rainy, and occasionally snowy. The average annual temperature is 13–14.4 °C, the sum of active temperatures (SAT) is 4192–4461 °C, the annual total solar radiation is 130–135 kcal/cm², most of it (80–90 kcal/cm²) occurs in the hot half of summer. The annual precipitation is 200–250 mm. The coldest month of the year is January (3.0–3.8 °C), the highest temperature is in July–August (up to 42 °C). There are 308 frost-free days, 220–230 sunny days. The peninsula is exposed to strong winds, which, along with improved transpiration in plants, leads to soil drying. It should also be noted that, as a manifestation of global climate change, in recent years there has been a tendency towards an increase in the amount of precipitation falling on the peninsula, which allows us to speak of a gradual change from a continental climate to a moderate one [1,4,5].

2.2. Soil Characteristics

The soils of the Peninsula are mainly sandy, calcareous, and the most common are saline gray-brown. They differ from each other only in the degree of salinity; the humus content is relatively high only on those located along the Absheron Canal [1,5].

2.3. Studied Varieties

The research focused on the Agadai, Gara Shany, Ag Shany, and Sarygila grape varieties, cultivated under the conditions of the Absheron Peninsula in irrigated vineyards. These vineyards featured 15-year-old plants with a multi-arm fan formation, a spacing of 1.5 meters between vines, and 2.5 meters between rows. Below are brief descriptions of the studied varieties (**Table 1**) [1,5]. A detailed description of the varieties can be found in the VIVC (Vitis International Variety Catalogue) database [6].

Table 1. The General Properties and VIVC Variety Numbers for Some Table Grape Varieties.

Variety	Variety Number VIVC	Brief Ampelographic Description
Ag Shany 	**11681**	A local variety of the Absheron Peninsula. The variety is close to the eco-geographical group of varieties of the Black Sea basin (proles pontica Negr.). The leaves are large, pentagonal, and weakly dissected. The leaf blade is strongly wavy, weakly vesicular. There is no pubescence on the lower surface. The petiole notch is tightly closed. The flower is functionally female. The bunch is medium or quite large, broadly conical, and the density varies greatly depending on pollination. The berry is large, oval or oblong, whitish-yellow, and golden-yellow when fully ripe. The skin is of medium thickness, covered with a thin layer of waxy coating. The pulp is tender, quite fleshy, juicy, and spreading. The juice is colourless. The taste is pleasant, with low acidity. Seeds 1–2, easily separated from the pulp. A variety of medium ripening periods. The duration of the growing season is 159 days. The variety is little damaged by powdery mildew, but is sensitive to downy mildew. Slightly damaged by Lobesia botrana. The variety is drought-resistant and is slightly damaged by spring frosts.
Gara Shany 	**21990**	A local variety of the Absheron Peninsula. The variety is close to the eco-geographical group of varieties of the Black Sea basin (proles pontica Negr.). The leaves are medium and large, medium-dissected, five-lobed, bright green, and rough. The petiolate notch is open. The flower is hermaphroditic. The bunches are medium-sized to large, conical or cylindrical-conical in shape, and loose to medium-dense. The berries are medium-sized or large, round, symmetrical, and dark blue. Covered with a thick wax layer. The pulp is juicy and aromatic. The taste is pleasant with a harmonious combination of sugar content and acidity. A mid-season ripening variety. The period from the beginning of bud break to full maturity is 130–131 days. The plants are vigorous. The yield is 75–100 c/ha. Gara shany is fairly resistant to downy mildew and powdery mildew, and is significantly damaged by Lobesia botrana. The variety is drought-resistant and is slightly damaged by frosts and freezes.
Agadai 	**95**	A local variety of southern Dagestan. Late-ripening variety. The yield on irrigated areas reaches 23 tons per hectare. The average weight of a bunch is 266 g, the sugar content of berries is 19.9%, and the acidity is 5.0 g/L. The variety is relatively suitable for transportation and winter storage. The leaves are large (up to 20 cm long), rounded, five-lobed, and medium-dissected. The main leaf colour is straw-yellow. The flower type is hermaphroditic. The clusters are large, cylindrical or cylindrical-conical, from loose to medium-dense. The average weight of a bunch on Absheron is 250–300 g. The berries are very large, almost round, slightly oblong, oval, light green with a yellowish tint. The pulp is dense, crispy. The taste is simple. The duration of the vegetation period from bud break to full ripening is 152 days. In the conditions of Absheron, the variety is moderately resistant to mildew and oidium, and resistant to grey rot.
Sarygila 	**10773**	An Azerbaijani variety, belonging to the ecological-geographical group of eastern varieties (proles orientalis). The leaf is medium, round, five-lobed, and medium-dissected. The leaf blade is slightly wavy, with slightly upwardly curved edges. The upper surface of the leaf is slightly vesicular. The petiolar notch is open, lyre-shaped or closed, with an elliptical lumen and a closed bottom. The flower is hermaphroditic. The bunch is medium, broadly conical, medium-dense, and the stalk of the bunch is short or medium. The berry is medium, round, and light yellow. The skin is relatively thin, strong, and covered with a slight waxy coating. The pulp is fleshy and juicy, melting. The taste is pleasant, with a harmonious combination of sugar content and acidity. There is one, sometimes two, seeds in a berry. A variety of early ripening periods. The duration of the vegetation period from the beginning of budbreak to full maturity is 120–122 days. The growth force of the plants is average. Productivity is 94 c/ha. Sarygila is rarely affected by fungal diseases such as powdery mildew and downy mildew. It is moderately susceptible to Lobesia botrana. It is quite drought-resistant.

2.4. Experimental Procedures

The grapes of three harvest periods were studied, with intervals between harvests of 6–8 days. The experiments were laid out in a fivefold repetition. We stored the grapes in refrigerators at a temperature of 0 °C to −1 °C and a relative humidity of 90–95%. Grapes harvested at different values of the sum of active temperatures were stored. During the storage period, we determined the yield of grapes that met quality standards through commodity analysis. The weight loss of grapes during storage was determined by weighing. The alcohol content in grapes was determined using the dichromate-iodometric method, which involves the oxidation of alcohol with potassium dichromate in an acidic medium and subsequent titration of the excess dichromate with iodine. To determine the intensity of respiration, a method based on measuring CO_2 released by berries was used. After harvesting and periodically during storage, the respiration rate of experimental grape samples was determined using the carbon dioxide emission method [22,30].

2.5. Data Analysis

For statistical analysis of the data obtained, we used one-way analysis of variance (ANOVA) and Tukey's HSD (Honestly Significant Difference) test ($p < 0.05$).

3. Results and Discussions

3.1. Shelf Life of the Varieties Studied

In **Table 2**, we present the results of the commodity analysis of grapes after 4 months of storage.

Table 2. Changes in the Commercial Quality of Grapes During Storage.

Variety	Collection Period	SAT, ºC	Storage Duration, Days	Standard Product, %	Monthly	
					Waste, %	Natural Weight Loss, %
Agadai	I	3164	129	92.07	1.84	3.17
	II	3334	121	92,94	1.75	2.69
	III	3447	115	98.11	0.49	2.55
Gara shany	I	3164	129	91.62	1.95	3.18
	II	3334	121	92.53	1.84	3.01
	III	3447	115	99.52	0.12	2.98
Ag shany	I	3164	129	66.13	7.88	3.49
	II	3334	121	68.49	7.82	3.30
	III	3447	115	78.63	5.58	2.77
Sarygila	I	3164	129	71.10	6.72	2.99
	II	3334	121	72.25	6.83	3.14
	III	3447	115	77.96	5.76	2.93

The results presented in the table show that the varieties Agadai and Gara shany have the longest shelf life; the yield of standard products after storage for the Agadai variety was 92.07–98.11%, for the Gara Shany variety, 91.62–99.52%. With the same storage period, the varieties Ag shany and Sarygila had the shortest shelf life; the yield of standard product was 66.13–78.63% for the Ag Shany variety, and 71.10–77.96% for the Sarygila variety. Grape losses during storage consist of microbiological and physiological spoilage, as well as natural loss, which is formed from water evaporation and losses of organic substances due to respiration. We made statistical analyses using a one-way ANOVA calculator and Tukey's HSD test for the determination of the influence of grape variety on weight loss during storage. The results were significant at $p < 0.05$ for all varieties studied (p-value for Agadai was 0.044379, 0.000185 for Gara Shany, 0.000598 for Ag Shany, and 0.000996 for Sarygila).

Respiration is accompanied by a decrease in mass due to the loss of dry matter and moisture. Due to the high water content, fruits are characterised by energetic respiration and a noticeable loss of mass. Evaporation leads to a change in the course of processes in grapes during storage and depends on the thickness of the bloom, the water-holding capacity of proteins, and other substances. Excessive water loss leads to berry wilting, significantly reducing the variety`s storage potential [15,16]. The Ag shany variety had the most noticeable drying of the rachis. The Agadai and Gara shany varieties suffered losses mainly from fallen berries. In Ag shany and Sarygila, along with losses of mechanical origin (falling, puncture, and partially crushing), a very large part of the losses came from microbiological spoilage. Some browning of the berries was observed by the end of storage in these same varieties.

3.2. Changes in the Content of Anaerobic Respiration Products

Respiration of grapes occurs in two directions: aerobic and anaerobic. Anaerobic respiration, occurring under conditions of oxygen deficiency, leads to increased consumption of nutrient reserves and rapid loss of nutritional value of berries. In addition, a significant amount of alcohol and acetaldehyde accumulates in the cells of grapes, which has a toxic effect on the cells of plant tissue. If during the ripening period of berries alcohol and acetaldehyde cannot accumulate to dangerous levels, since they are used by the plant in the process of synthesizing organic substances, then during storage, when synthetic processes almost completely stop, there is a real risk of accumulation of excessive amounts of volatile products of anaerobic respiration. The accumulation of these toxic products leads to rapid cell death, which is expressed in the browning of the pulp and the acquisition of specific "cooked" tones in the taste. The intensity of this process depends on the grape variety, growing and storage conditions [15]. During storage of grapes, the mass fraction of acetaldehyde and alcohol increases. The process of anaerobic respiration occurring in the tissues of berries has varietal characteristics. Grape varieties resistant to anaerobiosis withstand fairly high concentrations of volatile substances without browning. In varieties prone to early browning, acetaldehyde appears much earlier and by the end of storage has a higher value than in varieties that brown later or do not brown at all [13,15]. The results of our studies on changes in the alcohol and acetaldehyde content during storage are presented in **Table 3**.

Table 3. Changes in the Mass Fraction of Alcohol and Acetaldehyde in Grapes During Storage.

Variety	On Putting in Storage		After Storage	
	Alcohol, %	Acetaldehyde, mg/100g	Alcohol, %	Acetaldehyde, mg/100g
Agadai	0.17	0.17	0.20	0.37
Gara shany	0.18	0.16	0.23	0.33
Ag shany	0.17	0.19	0.26	0.44
Sarygila	0.20	0.19	0.30	0.46

As we can see, the grapes of the studied varieties contained a small amount of alcohol (0.17–0.20%) and acetaldehyde (0.16–0.19 mg/100 g) before being placed in storage. During further storage, their amount increased in all varieties; alcohol content reached 0.20–0.30%, and that of acetaldehyde reached 0.33–0.47 mg/100 g.

The results obtained indicate that the rate of anaerobic processes depends on the variety of stored grapes. The smallest increase in alcohol and acetaldehyde content was observed after four months of storage in the storable varieties of Agadai and Gara Shany: alcohol by 0.03% and 0.05%, respectively, and acetaldehyde by 0.20% and 0.17 mg%, respectively. The varieties of Ag Shany and Sarygila, which are not very suitable for long-term storage, showed a greater increase in the content of incomplete oxidation products in the berries — alcohol by 0.09 and 0.10%, respectively, and acetaldehyde by 0.25 and 0.27 mg/100 g. The significant accumulation of acetaldehyde in the berries of the Ag shany and Sarygila varieties by the end of storage was one of the reasons for the noticeable browning of these berries. Results of one-way ANOVA analysis and Tukey's HSD test on these indicators were significant at $p < 0.05$ for all varieties studied. Thus, the data we obtained allow us to conclude that the rate of anaerobic respiration, leading to the accumulation of under-oxidised products and, ultimately, to various physiological metabolic disorders, depends on the storage ability of the variety, i.e., resistance to anaerobiosis can serve as a characteristic of the storage ability of the variety.

3.3. Respiration Rate During the Storage Period

Respiration is a set of processes of oxidation of organic compounds by oxygen, with the release of energy necessary for the vital activity of living tissues of grapes, and the formation of carbon dioxide, water, and some intermediate products used in biosynthesis. It is the most important physiological process occurring in grapes during storage. The intensity of respiration can serve as an important sign of storage ability, as it is directly related to immunity. Respiration is a process inherent in all living organisms associated with enzyme activity and is an important source of energy necessary for metabolism. During respiration, plant and animal organisms consume atmospheric oxygen and oxidise organic matter to carbon dioxide and water. As a result of aerobic respiration, the energy contained in organic compounds is released, which is necessary for metabolism. In fruits, only what was accumulated during the growing period is used for oxidation. This indicates the important role of respiration in the post-harvest period of plant life. Respiration as a source of energy is necessary to maintain the structure of tissues, cells, and metabolism. Intermediate products serve as starting materials for various compounds, including those that determine the period of ripening and ageing, and resistance to diseases. Numerous investigations showed that the storageable varieties are distinguished by more equable respiration [13,18]. The results of our research confirmed that more storageable varieties, Agadai and Gara Shany, demonstrated less intensive respiration during the storage period (**Figure 1**). The respiration intensity of the Ag Shany and Sarygila varieties changed spasmodically.

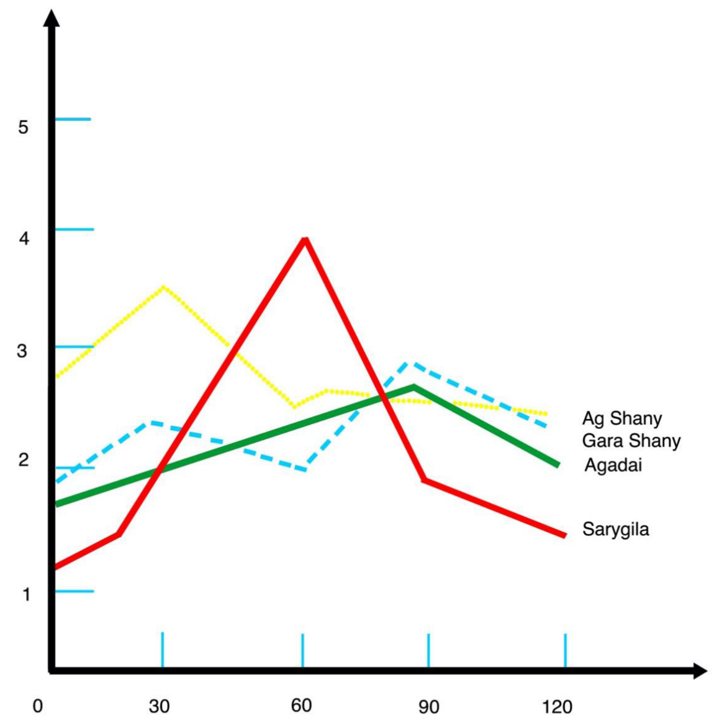

Figure 1. Respiration Intensity During the Storage Period.

X - storage duration, days;

XI - release of CO_2, ml/hour

According to literature sources [13,15], the peak of respiration—the climacteric crisis—is a factor that contributes to the intensive ageing and decay of fruits during storage. In our experiments, the Ag Shany and Sarygila varieties reached the climax of their respiration in the first half of the storage period. In contrast, the Agadai and Gara Shany varieties reached their climax in the last quarter of that period.

4. Conclusions

The results of our studies show that the Agadai and Gara Shany varieties have the highest storability, with a standard product yield of 70–100%, depending on the harvest time. These varieties also demonstrate the lowest amount of spoilage and weight loss during storage, which is primarily due to their varietal characteristics. The Agadai and Gara Shany varieties showed the lowest increase in anaerobic respiration products during storage. The alcohol content increased by 0.03 and 0.05%, respectively, and the acetaldehyde content increased by 0.20 and 0.27 mg/100 g, respectively. Thus, we can talk about resistance to anaerobiosis as a storability characteristic of a variety.

Studies of the intensity of grape respiration during storage indicate that the respiration of storable varieties is more equated and they reach the climacteric peak much later than less storable varieties. Reaching peak respiration can be seen as a sign that the grapes are becoming less suitable for further refrigeration storage. Thus, the intensity of respiration can serve as an indicator of the storability of grape varieties. The practical application of the results obtained during the research will help producers to more accurately determine the expected shelf life of stored grapes and choose the optimal time for their sale.

Author Contributions

Conceptualization, R.A.; methodology, R.A. and V.S.; investigation, R.A. and A.N.; writing—original draft preparation, R.A. and A.N.; writing—review and editing, R.A. and A.N. All authors have read and agreed to the published version of the manuscript.

Funding

This work received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data is unavailable due to privacy restrictions.

Acknowledgments

The authors express their gratitude to the staff of the Scientific Research Institute of Viticulture and Wine-making for administrative and technical support of this study..

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] Panahov, T., Salimov, V., 2012. Grape Varieties of Azerbaijan. Muallim: Baku, Azerbaijan. pp. 288. (in Azerbaijani)

[2] Di Lorenzo, C., Colombo, F., Sangiovanni, E., et al., 2019. Phenolic profile and biological activity of table grapes (Vitis vinifera L.). BIO Web of Conferences. 15, 04005. DOI: https://doi.org/10.1051/bioconf/20191504005

[3] De Lorenzis, G., Di Lorenzo, G.S., Failla, O., et al., 2015. Study of genetic diversity in V. vinifera subsp. sylvestris in Azerbaijan and Georgia and relationship with species of the cultivated compartment. Acta Horticulturae. 1074, 49–53. DOI: https://doi.org/10.17660/ActaHortic.2015.1074.6

[4] Maghradze, D., Rustioni, L., Turok, Y., et al., 2012. Caucasus and Northern Black Sea Region Ampelography. JKI – Julius Kühn-Institut: Quedlinburg, Germany. pp. 85–168.

[5] Salimov, V., Guliyev, V., 2021. Ampelography of Azerbaijan. Muallim Publishing: Baku, Azerbaijan. (in Azerbaijani)

[6] Julius Kühn-Institut - Federal Research Centre for Cultivated Plants (JKI), 2024. Vitis International Va-

riety Catalogue VIVC. Available from: https://www.vivc.de/ (access date: 02.06.2025).

[7] Zarmayev, A., 2022. Methodological approaches to establishing vineyards. News of the Chechen State University. 28(4), 45–49. DOI: https://doi.org/10.36684/12-2022-28-4-45-49 (in Russian)

[8] Mercenaro, L., Oliveira, A.F., Cocco, M., 2019. Yield and grape quality of three red grapevine cultivars (Vitis vinifera) in relation to altimetry. BIO Web of Conferences. 13, 02002. DOI: https://doi.org/10.1051/bioconf/20191302002

[9] Burger, D.A., Taylor, M.A., Jacobs, G., et al., 2013. Influence of harvest maturity on quality of cold stored Vitis vinifera L. cv. 'Thompson Seedless' and 'Red Globe' table grapes, with special reference to berry split. South African Journal of Plant and Soil. 22(1), 55–58. DOI: https://doi.org/10.1080/02571862.2005.10634681

[10] Westphal, M.I., Mehtiyev, M., Shvangiradze, M., et al., 2011. Regional Climate Change Impacts Study for the South Caucasus Region. UNDP: Tbilisi, Georgia. pp. 37–43. Available from: https://www.undp.org/sites/g/files/zskgke326/files/migration/ge/GE_SCCC-2011.pdf (cited 23.06.2025).

[11] Romero, I., Vazquez-Hernandez, M., Maestro-Gaitan, I., et al., 2020. Table Grapes during Postharvest Storage: A Review of the Mechanisms Implicated in the Beneficial Effects of Treatments Applied for Quality Retention. International Journal of Molecular Sciences. 21(23), 9320. DOI: https://doi.org/10.3390/ijms21239320

[12] Gorlov, S., Tyagusheva, A., Yatsushko, E., et al., 2020. Modern technologies of grape storage. Scientific Web Journal of Kuban Agrarian University. 159(05), 1–15. DOI: https://doi.org/10.21515/1990-4665-159-022 (in Russian)

[13] Djeneev, S., 1971. Biological specifications and directed growing of the table grape as a basis for its storage technology in Crimea [Doctoral Thesis]. Crimean Agricultural Institute, Simferopol. https://magarach-institut.ru/wp-content/uploads/2018/11/10.-Дженеев-С.Ю.-Биобиблиографический-указатель.pdf (cited 02.06.2025). (in Russian)

[14] Ahmadi Soleimanie, S., Vafaee, Y., 2023. Storability and postharvest quality of five Iranian grape cultivars during cold storage. Plant Physiology Reports. 28(2), 320–331. DOI: https://doi.org/10.1007/s40502-023-00723-x

[15] Magomedov, M., 2020. Grapes. Basics of Storage Technology. Lan: St. Petersburg-Moscow-Krasnodar, Russia. pp. 240. (in Russian)

[16] Yarmilka, V., 2010. Modern methods of fruits, vegetables and grape storage. Agronovost. Available from: https://agromage.com/stat_id.php?id=343 (cited 03.06.2025). (in Russian)

[17] Owoyemi, A., Balaklav, M., Kochanek, B., et al., 2024. Deviations from optimal storage temperature and its impact on postharvest quality of table grape cv. Scarlotta Seedless. Postharvest Biology and Technology. 215, 113013. DOI: https://doi.org/10.1016/j.postharvbio.2024.113013

[18] Leng, F., Wang, C., Sun, L., et al., 2022. Effects of Different Treatments on Physicochemical Characteristics of 'Kyoho' Grapes during Storage at Low Temperature. Horticulturae. 8(2), 94. DOI: https://doi.org/10.3390/horticulturae8020094

[19] Sama, H.K., 2024. Influence of storage systems on grapes value chains in Dodoma rural farmers. Agricultural Socio-Economics Journal. 24(3), 207–215. DOI: https://doi.org/10.21776/ub.agrise.2024.024.3.5

[20] Novello, V., Romanazzi, G., Altindisli, A., et al., 2017. Alternatives to sulphites and other preservatives for table and dried grapes (OIV Collective expertise). Available from: https://www.oiv.int/sites/default/files/2022-09/alternatives-to-sulphites-oiv-collective-expertise-2017_en.pdf (cited 22.06.2025).

[21] Sabýr, A., Sabýr, F.K., 2009. Postharvest treatments to preserve table grape quality during storage and approaches to find better ways alternative for SO2. Advances in Environmental Biology. 3(3), 286–296.

[22] Potapenko, A., Ganich, V., 2015. Inevitable losses during long-term storage of the grapes. Available from: https://russkiy-vinograd.ru/сборник-научных-трудов-русский-виног/потапенко-а-ю-ганич-в-а-неизбежные-пот/ (cited 18.06.2025). (in Russian)

[23] Grape.info. Respiration. Available from: https://vinograd.info/info/fiziologiya-vinograda/dyhanie.html (cited 04.06.2025). (in Russian)

[24] Gurbanov, M.R., Asadullayev, R.A., 2023. Development of grape microflora during the storage period. Azerbaijan Journal of Botany. 2(2), 42–48. DOI: https://doi.org/10.30546/ajb.2023.2.2.018

[25] Rana, S.S., Pradhan, R.C., Mishra, S., 2021. Physicochemical and Physiological Changes During Storage. In: Alam, T. (ed.). Packaging and Storage of Fruits and Vegetables: Emerging Trends. Apple Academic Press: New York, USA. pp. 1–24. DOI: https://doi.org/10.1201/9781003161165-1

[26] StudFiles, 2015. Biochemical processes during food storage. Available from: https://studfile.net/preview/2619487/page:25/ (cited 19.06.2025). (in

Russian)

[27] Blanckenberg, A., Opara, U.L., Fawole, O.A., 2021. Postharvest Losses in Quantity and Quality of Table Grape (cv. Crimson Seedless) along the Supply Chain and Associated Economic, Environmental and Resource Impacts. Sustainability. 13(8), 4450. DOI: https://doi.org/10.3390/su13084450

[28] Sharma, K.A., Sawant, S., Somkuwar, R.G., et al., 2018. Postharvest losses in grapes: Indian status. July 2018. DOI: https://doi.org/10.13140/RG.2.2.17999.89761/1

[29] Hamie, N., Zoffoli, J.P., Tarricone, L., et al., 2022. Rachis browning and water loss description during postharvest storage of 'Krissy' and 'Thompson Seedless' table grapes. Postharvest Biology and Technology. 184, 111758. DOI: https://doi.org/10.1016/j.postharvbio.2021.111758

[30] Samorodova-Bianki, G., 1989. Study of the biologically active substances of the horticultural crops. Methodical instructions. Leningrad: VIR. (in Russian)