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Natural Standard: Variability of Techno-Chemical Indicators of Traditional Guba Apple Varieties and Direct-Pressed Juices

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Research Article

Keywords: Apples from Guba, traditional varieties, techno-chemical potential, varietal characteristics

Posted Date: October 7th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11280533/v1

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Additional Declarations: The authors declare no competing interests.

Abstract

Guba-Khachmaz economic region is the main horticultural region of Azerbaijan with a unique microclimate and soil conditions that directly affect the biochemical composition of fruits. The purpose of this study is to identify the boundaries of natural fluctuations in the quality characteristics of traditional varieties of apples grown here (local and introduced). The research was conducted over three years (2021–2023). The material for laboratory studies was selected annually in three repetitions during the phase of removable fruit maturity in moderately intensive industrial plantings (rootstock MM 106, planting scheme 5 × 4 m, crown shape - oblique palmette) near the village. Zardabi, Guba district. The subject of the study included a comprehensive assessment of apples in the varietal section using a generally accepted approach and standard methods of chemical and technological variety testing. An analytical analysis of these key biochemical markers showed that the world's varieties (Golden, Starkrimson,) show biochemical maturity by the end of October: they process internal reserves (starch and acids) to improve taste. The local apples of Shikha Jana and Sarah Tursh showed ideal adaptation to the climate - by the end of October they accumulate an optimal balance of acids, sugars and moisture and have a high juice yield of 77.8 ± 0.7% and 75.5 ± 0.6%, respectively. Excellent juice yield above 75% was also shown by and . After 5 months of storage in controlled natural ventilation with a gradual decrease in temperature from + 10...+12°C in October to + 2...+4°C in winter, the content of vitamin C in apples decreased by 53.51 () – 94.82% (), acids – 24.24 () – 83.96% (). Thus, it was possible to identify the boundaries of natural fluctuations in the quality indicators of local apples and the unique potential of endangered ancient varieties for the food industry and breeding.

1 INTRODUCTION

Apples and apple juices are among the main export products of the agricultural sector of the Guba-Khachmaz region, where the favorable climate makes it possible to harvest rich yields of both local and global varieties adapted to the conditions of the region (Sadykov, 2021). The technological potential of local raw materials consists of their economic efficiency and biochemical properties (Sushko & Esina, 2025).

Modern processing plants operate in Guba, Khachmaz, and neighboring districts. They produce not only natural apple juices, but also concentrate, which is highly valued abroad and exported to European and Asian countries for the food industry.

Local producers have the technical and technological, and often analytical, capabilities to produce high-quality fresh, stored, and processed apple products that meet all the requirements of national and international regulatory documents. Control of juice authenticity (identification) requires a comprehensive analytical approach. Standard tests are not sufficient to rule out falsification and confirm the declared name of the juice. In-depth screening of indicators is required in combination with adjustment for natural factors—the climatic conditions of harvesting, the geography of cultivation, and

the specifics of technological processing—which objectively alter the natural composition of the product (Hafizov et al., 2021; Kolesnov, 2009; Meleshchenya et al., 2024; Vinothkanna et al., 2024).

The main international documents for assessing the quality and safety of fruit juices and nectars are the CODEX STAN 247–2005 standard (with subsequent updates through 2025) and the AIJN Code of Practice of the European Fruit Juice Association (AIJN, 1996; FAO, 2005). They regulate product composition, terminology, and control methods.

CODEX STAN 247–2005 was developed by the Codex Alimentarius Commission (FAO/WHO). It establishes global requirements for juices, nectars, and concentrated juices. It defines the minimum fruit content in nectars. It regulates the list of permitted food additives and labeling methods.

The AIJN Code of Practice was created by the European Fruit Juice Association (AIJN); it describes detailed authenticity criteria and physicochemical indicators of juices and is therefore used by producers and laboratories to detect falsification. It provides a clear distinction among the concepts of “100% juice,” “reconstituted juice,” “nectar,” and “fruit drink.” It contains requirements for the ripeness, purity, and safety of the source fruits and for identification—verification of compliance with the natural composition of the juice of a specific fruit- and strict restrictions on adding sugars, acids, and flavorings to natural juices. It includes: 29 Reference Guidelines for specific types of fruits and vegetables (each ranging from several pages to a full regulation); a Guide to Good Hygiene Practices; microbiological indicators, instructions for cleaning tanks, pesticide standards, and other specific guidelines. Because the AIJN regularly revises and supplements the standards separately (for example, making targeted amendments to the guidelines for apple, lemon, or pear juices), the total volume of the entire package of documents amounts to hundreds of pages.

Physicochemical and biochemical analysis, as constituent elements of the overall juice identification procedure, is carried out with mandatory consideration of information on varietal characteristics and the chemical composition of the source raw materials and finished products, as well as geographical, climatic, agricultural, and technological factors (Filatova et al., 2010; Lilishentseva et al., 2022).

Conducting analytical studies of raw materials and products in the enterprise's own laboratory or in third-party testing and research laboratories is an integral part of the production control system. In rare cases, because of the influence of a number of factors (for example, varietal characteristics), the composition of apple juice may deviate from accepted standards.

Under modern conditions, when the global market dictates its harsh rules, transnational commercial varieties of pears and apples have practically displaced local classics. By narrowing the assortment to a dozen global varieties, humanity puts food security at risk.

Today, an opposing trend is growing worldwide-a demand for authenticity and local products. Interest in old varieties is being revived among producers of traditional cider and organic juices. Amateur gardeners increasingly look in nurseries for seedlings “from childhood,” preserving them on their plots. Scientists

and enthusiasts create pomological orchards to preserve the gene pool for future generations of breeders.

Traditional apple varieties introduced early into the Guba-Khachmaz zone and folk-selection varieties historically grown here represent a unique gene pool characterized by high adaptability to local climatic conditions, resistance to pathogens, unique taste qualities, and a distinctive biochemical profile.

The present study is aimed at identifying the biochemical characteristics of local apples of old varieties and the natural limits of deviation in their quality indicators depending on varietal affiliation. Both fresh fruits and direct-pressed apple juices were evaluated.

2 RATIONALE FOR THE SELECTED DIRECTION AND THEORETICAL CONSIDERATIONS

Introduced old varieties are better adapted to local growing conditions and are often more resistant to pests and diseases and require fewer chemicals. From an economic point of view, traditional varieties offer advantages for small and organic farmers. These varieties are generally cheaper to grow and maintain because they do not require the same level of chemical treatment. Moreover, the high concentration of bioactive compounds and superior organoleptic properties make them an attractive option for the production of high-quality artisanal apple products, such as organic apple cider and fruit preserves. These products can be sold at a higher price in markets where consumers are willing to pay more for natural, minimally processed products.

Folk-selection (or local, indigenous) varieties are plants that arose as a result of many years of selection by peasants and amateur gardeners rather than in scientific institutes. The names of the creators of such varieties have been lost over the centuries, while the plants themselves were passed from generation to generation in a particular locality. People selected the best seeds or seedlings for taste, yield, and hardiness after severe winters or droughts. These varieties are ideally adapted to the local climate and soils and are resistant to local diseases. They represent valuable raw material for the production of functional foods, juices, ciders, and jelly products.

However, the preservation and successful integration of these varieties into breeding work to develop new local varieties and into processing are impossible without a detailed understanding of their behavior at different stages of maturity and systematized data on their biochemical and technological potential.

3 MATERIALS AND METHODS

The study was carried out at the Research Institute of Horticulture and Tea Growing of the Ministry of Agriculture of the Republic of *Azerbaijan* in accordance with the program and work plan for 2021–2023 approved by the institute's Academic Council, in the part concerning chemical and technological variety testing.

Material for laboratory studies was sampled annually in triplicate at the stage of harvest maturity of the fruits. The average sample size was 50 fruits.

The subject of the study was the scientific and methodological substantiation of the dynamics of apple fruit quality indicators as the fruits entered the stage of optimal harvest maturity and during their long-term holding in the postharvest period under warehouse conditions with controlled natural ventilation.

3.1 Type and location of the apple orchard

When apple orchards are established, the distance between rows and seedlings depends on the vigor of the rootstock: on vigorous rootstocks, the planting scheme is 6–7 × 4–5 m; on medium-vigorous rootstocks, 5–6 × 3–4 m; on semi-dwarf rootstocks, 4–5 × 2–3 m; and on dwarf rootstocks, 3–4 × 1–2 m.

Vigorous apple rootstocks are grown from seed of a wild forest apple or a hardy variety. These include seedlings of wild apple trees, the varieties "*Antonovka*" and "*Anis*," as well as clonal types MM 104, A 2, etc. They form the basis for large trees more than 4–5 meters tall with powerful roots, longevity of up to 40–50 years, and high resistance to drought and frost.

An apple orchard with a planting scheme of 5×4 m on a medium-vigorous rootstock with a "free or oblique palmette" crown belongs to the semi- or moderately intensive industrial type of orchard. In such orchards, the planting density is 500 trees per hectare; they are classified as moderately dense plantings. The rootstock type is medium-vigorous (clonal, for example, 54–118, MM-106), and the crown form is a flat palmette (Italian or oblique), which requires the installation of a lightweight trellis and regular formative pruning in one plane. Such an orchard occupies an intermediate position between traditional extensive orchards (on vigorous seedling rootstocks with free crowns) and modern intensive and high-intensive (dwarf) orchards.

In modern intensive orchards with a trellised "slender spindle," density ranges from 1250–2500 trees/ha and higher

The Guba-Khachmaz region is located in the northeast of *Azerbaijan* and consists of foothill and lowland zones with ordinary gray-brown and fertile meadow-brown soils.

The apples in this study were from varieties grown in the well-known moderately intensive orchards of the settlement of Zardabi, Guba District.

This settlement is literally immersed in greenery and is located 10 km lower than the district center, closer to the Caspian Sea. This difference in elevation and proximity to water create a special microclimate that makes our fruits exceptionally juicy and sweet. The terrain here is flat, the climate is milder than in the highlands, and the soils are more fertile (Holina & Bekerov, 2022). The average annual air temperature here is about 12°C. Precipitation remains within 340–350 mm per year, and the influence of northern winds is felt.

3.2 Objects of study

The objects of the study were 12 apple varieties of different origin: local autochthonous and old introduced varieties *Jir Gadzhi*, *Shihi Janı*, *Sary Tursh*, *Gara Tursh*, *Reinette de Champagne*, *Reinette Simirenko*, *Kandil Sinab*, and *Rosmarina Bianc*; commercial varieties of the global assortment *Golden Delicious* and *Starkrimson*; and new varieties of Azerbaijani breeding, *Naila* and *Azerbaijan*. Fruits for analysis were harvested at the stage of optimal harvest maturity, which occurred for the *Azerbaijan* variety in mid-September; for *Kandil Sinab* and *Rosmarina Bianc* in early October; and for the other varieties studied in late October.

Identifying the biochemical profile of autochthonous varieties (and it is precisely with them that the therapeutic and preventive properties of such apples, which can often be heard about from the local population, are associated) is especially important. This is especially so given that data on local folk-selection varieties are very fragmentary (Orudzhova et al., 2026), while they are gradually becoming a thing of the past (they have now been almost completely replaced by “glossy” novelties).

Golden Delicious is one of the most popular, widespread, and commercially successful apple varieties in the history of the global industry. It consistently ranks among the top 15 best-selling varieties in the world. Moreover, it is the genetic “parent” of a huge number of modern hybrids (for example, *Gala*, *Pinova*, *Eliza*, *Jonagold*). It continues to be planted in commercial orchards around the world. It was discovered as a chance seedling in the United States in 1905.

Starkrimson is a bud mutation of the *Starking Delicious* variety, found in 1952. It is a popular American “spur” type variety (with a compact crown). In the southern regions of Russia and the CIS countries, it remains a highly marketable commercial variety. Its fruits are valued for their intense dark-ruby color, excellent keeping quality, and transportability; therefore, demand for seedlings and fruits remains consistently high.

They can be considered classic varieties “with a history,” but the status “endangered” is not applicable to them. From the standpoint of pomology (the science of varieties), their status differs from that of genuinely old folk varieties.

Golden Delicious and *Starkrimson* are global industrial classics of the twentieth century. Not only do they not disappear, but they also continue to be the standards of taste and appearance on supermarket shelves. Truly old, traditional varieties (and those that are indeed partly disappearing from commercial circulation) were created over centuries, have spreading crowns, and are often unsuitable for modern intensive orchards.

3.3 Obtaining juice from apples

Juices (category “Direct pressing”) were obtained by mechanical grinding and pressing in a laboratory press. Before chemical analyses, freshly pressed juices were centrifuged at g = 2500 for 5 min to separate coarse insoluble particles.

3.4 Postharvest storage

After harvest, the apples were stored for 5 months under controlled natural ventilation with a gradual decrease in temperature from + 10...+12°C in October to + 2...+4°C in the winter months.

3.5 Location and methods for evaluating the chemical profile

The quantitative composition of the key substances of the chemical profile of the studied apple samples and the juices obtained from them was determined in the Laboratory of Fruit Processing and Storage Technology of the Research Institute of Fruit Growing and Tea Growing of the Ministry of Agriculture of *Azerbaijan* using standard equipment and generally accepted methods:

Total soluble solids (TSS) were determined according to Interstate Standard ISO 2173 – 2013 (ISO 2173 – 2013, 2019). Concentration is measured using digital refractometers (by light refraction) in g/100 g or °Brix (°Bx); 1 °Brix equals 1 gram of sucrose in 100 grams of solution (at the standard temperature of 20°C); it is measured using digital refractometers (by light refraction) or hydrometers/densitometers (by liquid density).

Brix measures the concentration of substances specifically in the expressed cell juice, not in the mass of the whole apple. When researchers or agronomists write, for example, “the soluble-solids content of apples of variety X is 12° Brix,” this is a professional shorthand. It means: “the cell juice extracted from this apple contains 12 g of soluble substances per 100 g of juice.”

DM (dry matter) was determined by the thermogravimetric method according to GOST (Russian State Standard) 33977 – 2016 (GOST 33977 – 2016, 2019);

Ascorbic acid was determined by the iodometric method according to GOST 24556-89 (GOST 24556-89, 2003);

Sugars (reducing sugar, sucrose, and total sugar) were determined according to GOST 34151 – 2017 (GOST 8756.13-87, 2010);

Titratable acidity was determined according to Interstate Standard ISO 750–2013 (ISO 750–2013, 2018).

3.6 Processing of primary data

Statistical processing of the primary data was carried out using the Statistica 10.0 package. For each test portion, the mean value from three parallel determinations and the standard deviation (SD) were calculated.

4 RESULTS

The obtained results are divided into two blocks: the first concerns the techno-chemical characteristics of harvest-maturity apples of traditional varieties; the second concerns quantitative changes in key nutrients during postharvest ripening of local apples.

4.1 Evaluation of the biochemical and technological potential of local apples

The most important biometric indicator is the average mass of a single fruit (both unripe and ripe). In horticulture, agronomy, and the food industry, it is used to assess crop quality, tree health, and the commercial value of fruits.

Fruit mass is a varietal characteristic. Different samples of ripe apples are divided into categories: small-fruited (up to 75 g); medium-fruited (75–125 g); large-fruited (125–175 g); very large (more than 175 g).

Fruit mass determines its further fate: large and medium apples go to the fresh market (they are more expensive), while small fruits are sent for processing (into juice, puree, cider).

Overly large fruits of the same variety often store worse because their tissues are looser and more susceptible to physiological disorders (for example, bitter pit). An optimal average mass guarantees a better storage life.

The difference in weight between an unripe and a ripe apple indicates the strength of the “inflow” of nutrients. If the mass of fruits on the tree has stopped increasing, this is one sign that harvest maturity has been reached.

Figure 1 clearly shows how the mass of an individual apple increased in each of the nine apple varieties included in the experiment over a 2.5-month segment of the growing season between 09.08 and 25.10.

As it can be seen from it, the weight of an individual fetus between these two dates increased by a maximum of 25.8 g (*Sary Tursh*)) and a minimum of 7.5 g (*Jir Gadzhi*).

By 25.10, the mass of an individual *Starkrimson* apple was 140.0 ± 4.7 g, and *Reinette Simirenko* was 130.0 ± 3.9 g; therefore, they can be classified as large-fruited.

The other varieties were in the medium-fruited category: *Gara Tursh* 96.0 ± 3.0 g; *Naila* 108.0 ± 3.5 g; *Golden Delicious* 113.3 ± 5.2 g; *Jir Gadzhi* 102.5 ± g; *Reinette de Champagne* 90.0 ± 2.8 g; *Shihi Janı* 94.0 ± 2.5 g; *Sary Tursh* 118.3 ± 4.0 g.

Apples of the *Azerbaijan* variety from the same orchard also came within our field of interest; their characteristics have to be discussed separately because this apple variety ripens about 40 days earlier than all 9 of the above-mentioned varieties.

Some apples of this variety continued to remain on the trees (because of incomplete harvesting in mid-September) until the very end of October; on 25.10, one such fruit weighed an average of 130 ± 4.5 g, which was almost 10 g more than on 09.08. At the same time, the late fruits seemed to retain and even increase the freshness of the fruits at harvest maturity.

Studying the chemical profile of apples of the above-mentioned varieties first at an early stage of their ripening at the end of the first ten days of August and then also during their harvest maturity made it possible to trace the changes that occurred during this period in the quantitative content of individual constituents of their component composition.

The biological value of apples is determined by the content of biologically active substances and vitamins, including ascorbic acid; therefore, its dynamics are of particular interest.

As shown in Fig. 1, in apples of all the above-mentioned varieties, the concentration of this vitamin increased slightly during the time interval from 09.08 to 25.10 (mg/100 g): *Gara Tursh*, from 2.46 to 2.82; *Naila*, 2.82–3.87; *Golden Delicious*, 3.17–3.87; *Jir Gadzhi*, 3.17–3.87; *Reinette de Champagne*, 2.46–4.22; *Reinette Simirenko*, 3.17–3.52; *Starkrimson*, 2.99–4.22; *Shihi Janı*, 2.82–3.17; *Sary Tursh*, 3.17–3.27.

As can be seen from these figures, the leading variety in the rate of increase in vitamin C content was *Reinette de Champagne* (during this period, the content of this vitamin in apples of this variety increased by 71.5%).

At harvest maturity, vitamin C content was highest in apples of the *Reinette de Champagne* (4.22 ± 0.25 mg/100 g) and *Starkrimson* (4.22 ± 0.10 mg/100 g) varieties.

Let us return again to the *Azerbaijan* variety: in the portion of apples of this variety that remained on the tree as a result of insufficiently complete harvesting, vitamin C content over the same period increased by 86.2% (from 3.95 ± 0.15 to 4.58 ± 0.20 mg/100 g).

Table 1 presents the quantitative content of dry matter and some key nutrients in unripe and ripe apples by variety, and Table 2 presents soluble dry matter and biocolloids.

Here and below, the varieties are divided into three groups:

1- Disappearing old introduced (*Reinette de Champagne* and *Reinette Simirenko*) and local (*Gara Tursh*, *Syry Tursh*, *Jir Gadzhi*, and *Shihi Janı*) varieties;

2- Global world varieties *Golden Delicious* and *Starkrimson*, which are still highly valued on world markets;

3- Relatively new varieties of *Azerbaijan*i breeding (*Naila*).

Table 1 shows that while, during the period covered by 09.08–25.10, the concentration of DM decreased in apples of most varieties, in the autochthonous varieties *Gara Tursh* and *Jir Gadzhi* in October it was much higher than it had been in August.

For all varieties, this was a period of continued growth in total soluble solids (TSS) content and sugar content. The minimum increase in TSS concentration was recorded for the *Sary Tursh* variety (from 9.9 ± 0.2 g/100 g to 10.3 ± 0.3 g/100 g), and the maximum for *Gara Tursh* (from 8.4 ± 0.3 g/100 g to 11.5 ± 0.3 g/100 g).

The leading varieties in TSS content on 25.10 were *Jir Gadzhi* (13.2 ± 0.4 g/100 g) and *Starkrimson* (13.0 ± 0.4 g/100 g).

During this period, the total sugar content (reducing sugar + sucrose) in the leading varieties for this indicator increased as follows: *Jir Gadzhi*-from 8.65 g/100 g to 10.50 g/100 g, or by 21.4%; *Reinette de Champagne*—from 6.44 g/100 g to 7.97 g/100 g (23.8%).

Despite the fact that the DM content in apples of the *Sary Tursh*, *Shihi Janı*, *Reinette de Champagne*, *Reinette Simirenko*, *Golden Delicious*, and *Starkrimson* varieties decreased, total sugar content increased in apples of all varieties without exception.

In apples of the *Gara Tursh*, *Sary Tursh*, *Reinette Simirenko*, *Reinette de Champagne*, and *Naila* varieties, at the second harvesting date in late October, acidity was somewhat lower than at the first date at the end of the first ten days of August. The acidity of apples of the other varieties (*Jir Gadzhi*, *Starkrimson*), on the contrary, increased by the second date or remained almost the same as at the first date (*Shihi Janı*).

The titratable acidity of *Sary Tursh* decreased substantially; that of *Reinette de Champagne* and *Reinette Simirenko*-by no more than 0.21 g/100 g; that of *Shihi Janı*, *Naila*, and *Golden Delicious* remained practically at the previous level; that of *Gara Tursh*, *Jir Gadzhi*, and *Starkrimson* became slightly higher.

Ultimately, on 25.10, depending on the variety, apple acidity varied within 0.22 ± 0.01 g/100 g (*Shihi Janı*) – 0.92 ± 0.05 g/100 g (*Reinette Simirenko*).

Table 1
Changes in the content of some key nutrients in apples of local and introduced varieties depending on the degree of maturity (g/100 g fresh weight).

Apple variety name	**Date (day, month)**	**DM**	**TSS**	**Reducing sugar**	**Sucrose**	**Acidity (as malic acid)**
Old introduced and local varieties						
Gara Tursh	09.08	12,3 ± 0,2	8,4 ± 0,3	5,64 ± 0,10	0,45 ± 0,01	0,70 ± 0,04
	25.10	14,6 ± 0,4	11,5 ± 0,3	6,94 ± 0,20	0,79 ± 0,02	0,67 ± 0,03
Sary Tursh	09.08	14,2 ± 0,4	9,9 ± 0,2	6,32 ± 0,11	0,12 ± 0,01	0,70 ± 0,03
	25.10	12,6 ± 0,2	10,3 ± 0,3	6,40 ± 0,12	2,10 ± 0,05	0,53 ± 0,02
Jir Gadzhi	09.08	12,4 ± 0,2	11,4 ± 0,3	6,72 ± 0,16	1,93 ± 0,04	0,33 ± 0,02
	25.10	16,4 ± 0,5	13,2 ± 0,4	9,64 ± 0,22	0,86 ± 0,02	0,43 ± 0,02
Reinette de Champagne	09.08	17,1 ± 0,5	10,0 ± 0,2	5,82 ± 0,11	0,62 ± 0,02	0,85 ± 0,04
	25.10	12,2 ± 0,2	11,5 ± 0,3	6,36 ± 0,12	1,61 ± 0,03	0,82 ± 0,04
Reinette Simerenko	09.08	14,1 ± 0,4	8,7 ± 0,1	5,22 ± 0,10	0,84 ± 0,02	1,03 ± 0,05
	25.10	13,3 ± 0,3	10,5 ± 0,2	7,04 ± 0,25	0.97 ± 0,02	0,92 ± 0,05
Shihi Janı	09.08	14,1 ± 0,3	9,4 ± 0,2	6,15 ± 0,12	0,76 ± 0,02	0,20 ± 0,01
	25.10	13,8 ± 0,4	11,5 ± 0,3	6,86 ± 0.18	2.45 ± 0,06	0,22 ± 0,01
Global commercial varieties “with a history”						
Golden Delicious	09.08	14,3 ± 0,4	9,8 ± 0,2	6,90 ± 0,14	0,38 ± 0,01	0,37 ± 0,02
	25.10	13,6 ± 0,3	12,5 ± 0,3	7,23 ± 0,26	2,26 ± 0,04	0,38 ± 0,02
Starkrimson	09.08	14,9 ± 0,4	10,0 ± 0,2	6,72 ± 0,13	1,83 ± 0,03	0,22 ± 0,01

Apple variety name	Date (day, month)	DM	TSS	Reducing sugar	Sucrose	Acidity (as malic acid)
	25.10	14,1 ± 0,3	13,0 ± 0,4	7,36 ± 0,25	2,93 ± 0,04	0,33 ± 0,01
Breeding varieties of the Research Institute of Fruit Growing and Tea Growing						
Naila	09.08	15.0 ± 0,4	9.8 ± 0,2	4,82 ± 0,10	1,64 ± 0,03	0,60 ± 0,03
	25.10	14,4 ± 0,4	12,5 ± 0,3	5,97 ± 0,11	3,17 ± 0,07	0,60 ± 0,03

The component composition of apples of the *Azerbaijan* variety, which we consider separately from the other varieties, on 09.08 and 25.10 was as follows (g/100 g): DM 14.5 and 12.5; TSS 10.8 and 10.0; reducing sugar 5.72 and 5.61; sucrose 2.47 and 2.85; acidity 0.75 and 0.77 (almost unchanged). In early August, the sugar concentration in apples of this variety was 8.19 g/100 g and remained almost unchanged until the very end of October (8.46 g/100 g). This means that almost all the starch that had been stored by apples of this variety at the beginning of vegetation had already broken down into sugar by harvest maturity (mid-September).

The data in Table 2, devoted to the chemical composition of direct-pressed juices from August and October apples of the above-mentioned varieties, show that TSS content in the juices increased sharply during the period from 09.08 to 25.10.

Calculations show that during the indicated period, TSS content in juices from apples of the *Reinette de Champagne*, *Jir Gadzhi*, and *Gara Tursh* varieties increased by 3 percent, and *Reinette Simirenko* by as much as 4 percent. In *Sary Tursh* apples it also increased, but to a lesser extent, from 9.8 ± 0.2 g/100 g to 10.5 ± 0.2 g/100 g, that is, by 0.7%.

Ultimately, on 25.10, TSS content in juices, depending on the apple variety, varied within 10.5 ± 0.2 g/100 g (*Sary Tursh*) -14.0 ± 0.4 (*Jir Gadzhi*) g/100 g (or °Brix).

The higher concentration of TSS in direct-pressed juices compared with the standard requirement for natural apple juice (10 °Brix) gives local processors several key advantages:

- -To obtain concentrated juice (usually up to 70 °Brix), less water needs to be evaporated, which reduces gas or electricity costs;
- - From one ton of such raw material, more concentrated juice is obtained than from apples with the minimum dry-matter content.

Table 2
Changes in the content of some key nutrients and vitamin C in direct-pressed juices from apples of local and introduced varieties depending on the degree of maturity (g/100 g).

Apple variety name	Date (day, month)	TSS	Reducing sugar	Sucrose	Acidity (as malic acid)	Vitamin C (mg/100 g)
Old introduced and local varieties						
Gara Tursh	09.08	9,0 ± 0,2	5,97 ± 0,11	0,85 ± 0,02	0,70 ± 0,03	2,99 ± 0,08
	25.10	12,0 ± 0,3	7,54 ± 0,22	1,23 ± 0,04	0,60 ± 0,03	2,82 ± 0,07
Sary Tursh	09.08	9,8 ± 0,2	6,57 ± 0,12	0,72 ± 0,03	0,87 ± 0.04	3,17 ± 0,09
	25.10	10,5 ± 0,2	7,46 ± 0,20	0,46 ± 0,01	0,67 ± 0,03	3,52 ± 0,12
Jir Gadzhi	09.08	11,0 ± 0,3	6,81 ± 0,13	1,60 ± 0,05	0,40 ± 0,02	3,34 ± 0,11
	25.10	14,0 ± 0,4	8,56 ± 0,26	2,42 ± 0,07	0,50 ± 0,02	3,17 ± 0,10
Reinette de Champagne	09.08	9,2 ± 0,2	5,81 ± 0,11	0,94 ± 0,03	0,93 ± 0,04	2,46 ± 0,06
	25.10	12.5 ± 0,3	6,82 ± 0,18	1,95 ± 0.05	0.90 ± 0,04	2,82 ± 0,06
Reinette Simerenko	09.08	9,0 ± 0,2	5,41 ± 0,11	1,56 ± 0,04	1,03 ± 0,05	3,17 ± 0,10
	25.10	13,0 ± 0,4	5,61 ± 0,11	3,17 ± 0,08	0.97 ± 0,05	3,52 ± 0,12
Shihi Janı	09.08	9,8 ± 0.2	6,82 ± 0,17	0,60 ± 0,01	0,23 ± 0,01	2,82 ± 0,06
	25.10	12,0 ± 0,3	7,11 ± 0,14	1,97 ± 0,05	0,23 ± 0.01	2,81 ± 0,06
Global commercial varieties “with a history”						
Golden Delicious	09.08	9,8 ± 0,2	6,72 ± 0,13	1,11 ± 0,03	0,43 ± 0,02	3,52 ± 0,13
	25.10	13.5 ± 0,4	7,57 ± 0,20	2,95 ± 0,08	0,60 ± 0,03	1,17 ± 0,03
Starkrimson	09.08	10,3 ± 0.2	7,06 ± 0,19	1,51 ± 0,04	0.33 ± 0,01	2,82 ± 0,06

Apple variety name	Date (day, month)	TSS	Reducing sugar	Sucrose	Acidity (as malic acid)	Vitamin C (mg/100 g)
	25.10	12,5 ± 0,3	7,84 ± 0,25	3,51 ± 0.10	0,90 ± 0,04	2,18 ± 0,05
Breeding varieties of the Research Institute of Fruit Growing and Tea Growing						
Naila	09.08	9,3 ± 0,2	5,81 ± 0,11	0,61 ± 0,01	0,70 ± 0,03	2,82 ± 0,06
	25.10	12,5 ± 0,3	6,47 ± 0,12	1,15 ± 0,03	0,57 ± 0,02	2,82 ± 0,06

The component composition of August and October direct-pressed juices from the separately considered apples of the *Azerbaijan* variety was as follows (g/100 g): TSS 11.2 and 12.0; reducing sugar 5.97 and 5.64; sucrose 2.55 and 3.82; acidity 0.87 and 0.70. TSS content increased between the beginning of August and the end of October from 11.2 to 12.0 g/100 g, that is, by 0.8%.

Table 3, which presents data on the yield of direct-pressed juice from unripe and ripe apples and on its taste and color, shows that juice yield and its sensory properties depend strongly not only on the time of apple harvest (and therefore on the degree of maturity), but also on varietal affiliation.

In some varieties (*Naila*, *Gara Tursh*, *Sary Tursh*, *Jir Gadzhi*, *Reinette Simirenko*), juice yield from fruits at the end of the first ten days of August was much lower than from fruits at the end of October, whereas in others (*Reinette de Champagne*, *Golden Delicious*, and *Starkrimson*) it was higher. Juice yield from *Shihi Janı* apples increased by the time they reached full ripeness, but only slightly.

By the end of the second ten days of October, the lowest juice yield among all 9 varieties was shown by *Starkrimson* (56.8 ± 0.5%), and the highest by *Reinette de Champagne* (77.8 ± 0.7%), *Reinette Simirenko* (77.8 ± 0.7%), *Shihi Janı* (77.8 ± 0.7%), Glden Delicious (75.0 ± 0.7%), and *Sary Tursh* (75.5 ± 0.7%).

A juice yield of 75–78% is a very high indicator for apples, close to the biological maximum, whereas 55–57% is a low indicator characteristic of somewhat dry or overripe fruits.

To better understand these figures, they should be compared with processing standards:

- - Above 75% (*Reinette Simirenko*, *Reinette de Champagne*, etc.) is an excellent result. In industrial production, 65–70% is considered a good juice yield. An indicator close to 80% means that the fruits are maximally juicy, have a fine cellular structure, and readily release moisture during pressing.
- - Below 60% (*Starkrimson*) is low. Processing such apples into juice is economically unprofitable- almost half the weight will go into dry pomace.

The superiority of the leading varieties by mid-October is due to three main factors:

1. The end of October is the time when late-winter and winter varieties (such as *Reinette Simirenko*, *Reinette de Champagne*, *Golden Delicious*) are just reaching their optimal harvest or technological maturity. During this period: the starch in the fruits has already turned into sugar; the cell walls have softened but have not yet broken down; the apple tissues are maximally saturated with juice, which is easily separated during pressing.

At the same time, earlier or specific varieties (for example, *Starkrimson*) by mid-October under *Azerbaijan*i conditions may simply become overripe directly on the tree or during storage. When overripe, apple flesh becomes “cottony,” mealy, and the juice is firmly bound by pectins and is hardly released during pressing.

1. 2. The leading varieties of the Reinette group and *Golden Delicious* have dense, fine-grained, and crisp flesh. When such apples are crushed, an ideal structure (mash) is formed that allows juice to pass very well through filters and presses. The outsider variety - *Starkrimson* - is genetically prone to rapid loosening of the flesh. When overripe *Starkrimson* is crushed, a thick puree is formed, during the pressing of which the juice also remains blocked in the pomace.
2. 3. Juice yield directly depends on the amount of soluble pectins: if there is too much soluble pectin (which occurs when fruits become overripe), the juice becomes viscous, turns into jelly, and is retained inside the cells.

The leading autumn-winter varieties in mid-October maintain a balance in which pectin hydrolysis ensures juiciness but does not turn the flesh into mush. For local *Azerbaijan*i varieties (such as *Shihi Janı* and *Sary Tursh*), this shows their ideal adaptation to the climate—by October they accumulate an optimal balance of acids, sugars, and moisture.

The same table shows that after 4 hours of holding in open air, direct-pressed juices from ripe *Sary Tursh*, *Reinette de Champagne*, *Shihi Janı*, and *Naila* apples either still remained light or darkened only slightly, indicating their relative resistance to undesirable enzymatic transformations.

The juice yield from slightly sour-tasting *Azerbaijan* apples at these two extreme dates was 70.0% at the beginning of August and 55.4% at the end of October; moreover, the August juice remained light after 4 hours of exposure to air, whereas the October juice darkened slightly.

Table 3
Changes in the yield and sensory properties of direct-pressed juices from apples of local and introduced varieties depending on the degree of maturity.

Apple variety name	**Date (day, month)**	**Taste**	**Color (after 4-hour exposure to open air)**	**Juice yield, % of the mass of processed fruits**
Old introduced and local varieties				
Gara Tursh	09.08	Slightly tart	Light yellow	62,1 ± 0,5
	25.10	Slightly sour	Dark	69,0 ± 0,6
Sary Tursh	09.08	Sour	Light	64,9 ± 0,5
	25.10	Slightly sour	Light	75,0 ± 0,6
Jir Gadzhi	09.08	Sweet	Somewhat dark	63,2 ± 0,6
	25.10	Sweet	Dark	70,2 ± 0,5
Reinette de Champagne	09.08	Sour	Somewhat light	80,1 ± 0,7
	25.10	Sour	Light	77,8 ± 0,7
Reinette Simerenko	09.08	Sour	Very light	71,4 ± 0,6
	25.10	Sour	Dark brown	77,8 ± 0,7
Shihi Janı	09.08	Sweet	Light	76,4 ± 0,7
	25.10	Sweet	Somewhat light	77,8 ± 0,7
Global commercial varieties “with a history”				
Golden Delicious	09.08	Sour-sweet	Light	78,0 ± 0,7
	25.10	Slightly sweet	Dark	75,0 ± 0,7
Starkrimson	09.08	Sweet	Somewhat dark	68,2 ± 0,6
	25.10	Sweet	Very dark	56,8 ± 0,5
Breeding varieties of the Research Institute of Fruit Growing and Tea Growing				
Naila	09.08	Sour-sweet	Light	48,6 ± 0,4
	25.10	Sweet	Somewhat light	73,6 ± 0,6

Juice yield from apples is the main technological and economic indicator of production efficiency, defining the percentage ratio of the mass of obtained juice to the mass of processed fruits. The production cost of the finished product and the profitability of the enterprise depend directly on the yield percentage. Technical ripeness is determined, among other things, by flesh firmness. The use of special pectolytic enzyme preparations destroys cellular structures and can substantially increase juice yield (up to 75–95% depending on the pressing technology).

4.2 Quantitative dynamics of key nutrients in apples during their postharvest ripening

There is a relationship between the biochemical processes that occur in fruits after harvest and the content of beneficial substances.

After harvest, the apples were stored for 5 months under controlled natural ventilation with a gradual decrease in temperature from + 10...+12°C in October to + 2...+4°C in the winter months.

The experiment included harvest-maturity apples of six varieties: *Kandil Sinab* and *Rosmarina Bianc*, *Reinette de Champagne*, *Reinette Simirenko*, *Jir Gadzhi*, and *Sary Tursh*. *Kandil Sinab* and *Rosmarina Bianc* apples reach harvest maturity a month earlier (at the end of September-the first days of October), so they were removed from the trees and placed in storage four weeks earlier earlier than the apples of the other four varieties.

Figure 3 shows the change in vitamin C content in apples during their postharvest ripening under the conditions of our experiment.

As can be seen from it, vitamin C content in the apple samples decreased continuously, and most rapidly in the first month. After 5 months of storage, vitamin C content in all samples was significantly below the initial level.

During this time, the content of this vitamin decreased markedly: in *Reinette de Champagne* apples-from 5.00 to 1.23 mg/100 g; in *Reinette Simirenko* apples-from 6.51 to 2.82 mg/100 g; *Kandil Sinap*-from 3.69 to 0.88 mg/100 g; *Rosmarina Bianc*-from 2.28 to 1.06 mg/100 g; *Jyr Gadzhi*-from 4.75 to 1.06 mg/100 g; and *Sary Tursh*-from 7.92 at the beginning to 0.41 mg/100 g at the end of storage.

The percentage decrease depending on the apple variety was: *Reinette de Champagne* 75.4; *Reinette Simirenko* 56.68; *Kandil Sinap* 76.16%; *Rosmarina Bianc* 53.51%; *Jir Gadzhi* 77.69%; *Sary Tursh* 94.82.

The highest percentage decrease in vitamin C was in *Kandil Sinap* apples (76.16%), and the lowest in *Rosmarina Bianc* apples (53.51%), which differed from apples of the other varieties also by the lowest initial content of this vitamin (2.28 mg/100 g of their fresh weight).

Table 3 shows that during these five months of storage, the titratable acidity of the apples also decreased significantly.

Simple calculations showed that during this time apple acidity decreased by 36.67 (*Reinette de Champagne*) – 83.96 (*Reinette Simirenko*) – 57.5 (*Kandil Sinap*) – 52.86 (*Rosmarina Bianc*) – 48.48 (*Jir Gadzhi*) and 24.24 (*Sary Tursh*) percent.

Table 3
Dynamics of nutrients in introduced and local apple varieties during storage in an uncontrolled environment (g/100 g fresh weight)

Apple varieties	Stages (months)	TSS	DM	Reducing sugar	Sucrose	Acidity (as malic acid)
Old introduced varieties						
Reinette de Champagne	0	11,0 ± 0,2	12,1 ± 0,2	6,13 ± 0,13	1,17 ± 0,04	0,90 ± 0,07
	1	11,5 ± 0,2	12.4 ± 0,2	7,44 ± 0,14	1.33 ± 0,04	0,87 ± 0,07
	2	11,5 ± 0,2	16,3 ± 0,4	7,76 ± 0,14	1,70 ± 0,05	0,67 ± 0,05
	5	11,5 ± 0,2	16,6 ± 0,4	8,31 ± 0,21	1,75 ± 0,05	0,57 ± 0,04
Reinette Simirenko	0	10,5 ± 0,2	13,3 ± 0,2	6,97 ± 0,13	0,69 ± 0,01	1,06 ± 0,08
	1	11,7 ± 0,2	13,5 ± 0,2	6,86 ± 0,13	2,05 ± 0,07	0.72 ± 0,07
	2	11,5 ± 0,1	13,8 ± 0,2	7,07 ± 0,14	1,02 ± 0,03	0,50 ± 0,04
	5	11,5 ± 0,2	14,5 ± 0,3	7,61 ± 0,14	2,03 ± 0,07	0,17 ± 0,01
Kandil Sinap	0	12,5 ± 0,3	16,6 ± 0,4	7,15 ± 0,14	0,69 ± 0,01	0,40 ± 0,04
	1	12,5 ± 0,3	14,2 ± 0,3	8,09 ± 0,23	1,64 ± 0,05	0,31 ± 0,02
	2	12,0 ± 0,3	14,9 ± 0.3	9,38 ± 0,26	0,80 ± 0,01	0,20 ± 0,01
	5	12,5 ± 0,3	17,0 ± 0,5	9,68 ± 0,27	1,45 ± 0,03	0,17 ± 0,01
Rosmarina Bianc	0	11,0 ± 0.2	12,5 ± 0.2	5,60 ± 0,11	2,57 ± 2,09	0,70 ± 0,07
	1	12,0 ± 0,3	13,5 ± 0,2	5,66 ± 0,11	2,37 ± 2,08	0,68 ± 0,05
	2	11,2 ± 0,2	13,9 ± 0,2	6,27 ± 0,13	2,26 ± 0,07	0,35 ± 0,02
	5	11,5 ± 0,2	14,8 ± 0,3	6,72 ± 0,13	2,53 ± 2,08	0,33 ± 0,02
Local autochthonous varieties						

Apple varieties	Stages (months)	TSS	DM	Reducing sugar	Sucrose	Acidity (as malic acid)
Jyr Gadzhi	0	12,0 ± 0.3	15,5±	7,52 ± 0,14	1,16 ± 0,03	0,33 ± 0,02
	1	11,5 ± 0,2	13,9 ± 0,2	8,16 ± 0,22	1,13 ± 0,03	0,32 ± 0,02
	2	13,0 ± 0,4	14,8 ± 0,3	9,05 ± 0,26	0,85 ± 0,02	0,17 ± 0,01
	5	12,0 ± 0,2	15,5 ± 0,4	8,94 ± 0,25	0,60 ± 0,01	0,17 ± 0,01
Sary Tursh	0	10,5 ± 0.1	13,7 ± 0,2	7.06 ± 0,14	0,85 ± 0,02	0,66 ± 0,05
	1	11,0 ± 0,2	12,9 ± 0,2	7,76 ± 0.14	0,77 ± 0,02	0,63 ± 0,05
	2	11,0 ± 0.2	13,3 ± 0,2	8,27 ± 0,24	0,61 ± 0,01	0,50 ± 0,04
	5	10,5 ± 0.1	13,9 ± 0,3	6,90 ± 0,13	0.83 ± 0,02	0,50 ± 0,04

At the same time, over the entire storage period, the concentration of DM in apples increased: by 37.19% (*Reinette de Champagne*); 9.02% (*Reinette Simirenko*); 2.41% (*Kandil Sinap*); 18.40% (*Rosmarina Bianc*). The exception was the local indigenous forms *Jyr Gadzhi* (for which this indicator remained at 15.5% of fresh weight) and *Sary Tursh* (for which this indicator this indicator was 13.7% at the beginning of storage and 13.9% of fresh weight at the end, that is, it almost did not change).

The increase in dry-matter concentration in apples during storage under uncontrolled conditions is mainly associated with intensive evaporation of moisture (weight loss). When fruits lose water, the total mass of the apple decreases, as a result of which the relative proportion of dry matter (sugars, acids, pectins) in the remaining volume mathematically increases.

However, there are exceptions to this rule. A decrease or unchanged level of dry matter in some varieties is due to the following biological factors.

Apples are living organisms. During storage, they consume sugars and organic acids for respiration. If the rate of sugar breakdown in a variety exceeds the rate of moisture loss, the absolute and relative amount of dry matter decreases.

Varieties with thick skin, a strong cuticular layer, or an abundant wax coating evaporate water very slowly. Their weight loss is minimal, so the consumption of dry matter for respiration comes to the forefront.

Moreover, in our experiment this almost did not change the overall trend in the dynamics of reducing and total sugar, which was increasing in all varieties. Thus, in *Reinette de Champagne* apples, reducing and total sugar content increased by 35.56 and 37.81%, respectively; *Reinette Simirenko*-9.18 and 25.85%; *Kandil Sinap* – 35.38 and 41.96%; *Rosmarina Bianc*-20.0 and 13.78%; *Jir Gadzhi*-9.56 and 21.43%; and only in *Sary Tursh* apples did the reducing and total sugar content by the end of storage decrease compared with their initial content by 2.27 and 2.28%.

The main reason for the increase in apple sugar content during storage is the breakdown (hydrolysis) of starch into simple sugars.

During ripening, fruits accumulate starch. During subsequent storage, this complex carbohydrate is broken down into glucose, fructose, and sucrose. Because the amount of starch decreases and the proportion of free sugars increases, apples become sweeter and softer.

Thus, over the entire storage period there was a decrease in the content of some substances relative to the initial content at the beginning of storage (minimum–maximum): vitamin C-53.51% (*Rosmarina Bianc*) – 94.82% (*Sary Tursh*); titratable acids-24.24% (*Sary Tursh*) – 83.96% (*Reinette Simirenko*).

At the same time, reducing and total sugar content in apples at the end of storage became higher than at its beginning: in *Reinette de Champagne* apples by 35.56 and 37.81%; *Reinette Simirenko*-9.18 and 25.85%; *Kandil Sinap*-35.38 and 41.96%; *Rosmarina Bianc*-20.0 and 13.78%; *Jir Gadzhi*-9.56 and 21.43%, respectively. The exception was *Sary Tursh* apples, in which reducing and total sugar content decreased compared with their initial content at the beginning of storage by 2.27 and 2.28%, respectively.

During the same time, the total dry-matter content in apples increased compared with its initial content at the beginning of storage by a minimum of 2.41% (*Kandil Sinap*) and a maximum of 37.19% (*Reinette de Champagne*).

This means that these apples became drier and less juicy.

The exception was the local indigenous forms *Jir Gadzhi* (for which this indicator remained at 15.5% of the fresh weight of the apples) and *Sary Tursh* (for which this indicator was 13.7% at the beginning of storage and 13.9% of the fresh weight of the apples at the end).

5 DISCUSSION

These data make it possible to draw several important conclusions about the biology of apple development, varietal characteristics, and their economic value.

The data clearly divide the varieties by mass at the time of harvest (October 25). Large-fruited leaders (*Starkrimson*, *Reinette Simirenko*, *Azerbaijan*) and medium-fruited varieties (the rest, ranging around 90–118 g) stand out. This indicates a strong influence of genotype on final fruit size.

In accordance with European marketing standards (in particular, UNECE Standard FFV-50 and EU Regulations), the mass of fresh market apples is regulated by a lower limit, while the upper mass limit is not restricted by regulation-it is dictated exclusively by the varietal characteristics of the fruit. At the same time, uniformity of apple weight within a single package is strictly controlled (UNECE, 2014, 2020).

The mass of an individual fruit for admission to the European market depends on its degree of maturity and sugar content (Brix level)-90 grams is the standard minimum weight for all varieties (equivalent to a fruit diameter of at least 60 mm); 70 grams is allowed as an exception if the sugar level in the fruit is equal to or exceeds 10.5° Brix and the minimum diameter is at least 50 mm.

For all commercial classes (Extra, I, and II), up to 10% (of total weight or number) of fruits that do not comply with the sizing rules is allowed. However, this tolerance must not be used to smuggle excessively small produce: no apple in a lot may be more than 10 grams lighter than the minimum threshold (that is, weigh less than 80 g for standard varieties or less than 60 g for high-sugar varieties). The maximum permissible difference from the largest fruit in the package is: for 90 g-no more than 15 g; from 90 g to 135 g—no more than 20 g; from 135 g to 200 g-no more than 30 g; from 200 g to 300 g-no more than 40 g; more than 300 g-no more than 50 g.

These sizing and uniformity rules do not apply to apples sold loose or in small consumer packages. For all classes, a deviation of no more than 10% of the total weight of fruits that do not meet the sizing requirements is allowed, but their mass must not be more than 10 grams below the minimum.

The difference in mass gain shows how different varieties assimilate nutrients in late summer and autumn (the strength of fruit filling). The *Sary Tursh* and *Gara Tursh* varieties showed the maximum increase (more than 23–25 g), which may indicate their active vegetation precisely during this period. The *Jir Gadzhi* variety had the minimum increase (7.5 g). In contrast, medium-fruited varieties such as *Sary Tursh* grew actively precisely during the autumn interval studied.

Normally, as apples ripen, starch is hydrolyzed into sugars and organic acids are consumed for fruit respiration. If the acidity of *Gara Tursh* apples decreased: this confirms the hypothesis of classical ripening (acid is consumed for respiration). If the acidity of *Jir Gadzhi* apples) increased: this fits perfectly with their anomalous increase in DM-the fruits simply lost moisture (dried out), so the acid concentration increased in the same way as the dry-matter concentration.

However, the obtained data set contains several unique varietal characteristics.

The main direction of change for most varieties is standard: a decrease in dry matter (DM) with a simultaneous increase in total sugar, which is understandable.

The fruits actively respire. Soluble dry matter (mainly organic acids and some carbohydrates) is consumed to maintain vital activity. A slight redistribution of moisture may also occur.

Hydrolysis (breakdown) of previously accumulated starch and complex carbohydrates into simple sugars (glucose, fructose, sucrose) occurs. That is, the total mass of dry matter decreases, but the concentration of free sugars within that mass increases.

The analysis reveals a clear division of the varieties into four biological groups depending on their metabolism.

The first group includes “classical inverts”-varieties with normal ripening such as *Reinette de Champagne*, *Reinette Simirenko*, *Starkrimson*, *Golden Delicious*, *Shihi Janı*, and *Naila*. These varieties behave predictably: DM decreases, sugar increases, and acidity gradually decreases or remains stable. Late-autumn and winter varieties (Reinettes, Golden, *Starkrimson*) are just reaching harvest or consumer maturity during this period. Their taste qualities improve (the taste becomes sweeter, excessive astringency disappears).

The nature of the second group (*Gara Tursh* and *Jir Gadzhi*) is determined by “carbohydrate anomalies” (autochthonous accumulators), in which there was a substantial increase in DM against the background of an overall increase in sugar. This is an extremely interesting phenomenon for the August-October period. An increase in dry-matter density can occur in two cases: 1- the fruits, while remaining on the tree, lost water, as a result of which the concentration of all dry matter (including sugars) mathematically increased; 2- local (autochthonous) varieties are genetically adapted to an arid or specific climate and are able to continue synthesizing soluble carbohydrates through an intensive inflow of assimilates from the leaves.

The third group (*Sary Tursh*) is best characterized by the phrase “acid extreme.” The *Sary Tursh* variety is characterized by a strong, rapid decrease in acidity. The name of the variety itself (tursh-sour) indicates an initially high acid content. Their rapid decline indicates that this variety has an extremely high respiration intensity. Organic acids (malic, citric) in this variety are involved in the Krebs cycle (respiratory metabolism) much more strongly than in other varieties. By the end of October, this variety most likely sharply loses its technological (canning) properties and harmony of taste, becoming “bland” or overripe.

Many factors influence the yield and chemical composition of apple juice, including the properties of the raw material (Kokh, 2021).

The dynamics of juice yield depend on the balance between the breakdown of rigid protopectin (which increases juice release) and overripening of the flesh (which reduces juice yield). This balance is individual for each variety.

The cell walls of August fruits are retained by insoluble pectin, which causes their rigidity. It firmly binds the cells together and retains moisture inside them like a sponge. When such apples are pressed, the tissues release moisture poorly.

During ripening (October), protopectin breaks down into soluble pectin under the action of enzymes. The cell walls become thinner, the connection between cells weakens, and the juice separates much more

easily. This is precisely why juice yield in the *Naila*, *Gara Tursh*, *Sary Tursh*, *Jir Gadzhi*, and *Reinette Simirenko* varieties rises sharply by October.

In the group of "loose" and mealy varieties (*Reinette de Champagne*, *Golden Delicious*, *Starkrimson*): at the stage of overripeness or full ripeness, the flesh becomes loose, crumbly, or "cottony." When such ripe apples are pressed, a puree-like mass is formed that blocks the outflow of liquid. Conversely, in the unripe state (in August), their flesh is still dense, crisp, and juicy, which makes it possible to press more juice from them before they turn into mush.

In some varieties (*Shihi Janı*), the cellular structure changes only slightly; they retain flesh density for a long time, and therefore their juice yield remains stable throughout the entire period.

Between August and October, the tree continues to nourish the fruits. Depending on the variety, the absolute content of free (juice) water relative to dry matter may increase in apples, which directly affects juice release.

Varieties with relatively low juice yield in October (*Starkrimson*-56.8%) may be genetically predisposed to a thicker cell wall or an increased content of dense dry matter (cellulose, hemicellulose). In contrast, the triumvirate of juice-yield leaders (*Reinette de Champagne*, *Reinette Simirenko*, *Shihi Janı*—77.8%) has a delicate cellular structure that is easily destroyed under press pressure during ripening.

Freshly pressed apple juice from apples of the *Jir Gadzhi*, *Gara Tursh*, *Reinette Simirenko*, Golden Deishesh, and *Starkrimson* varieties quickly darkens in air because of enzymatic oxidation. This process occurs in several stages involving organic compounds (polyphenols) and the enzyme polyphenol oxidase (tyrosinase), which are contained in apples. When the juice is pressed, the apple cells are destroyed; because of this, substances that were previously located in different parts of the cell mix together. As soon as the juice comes into contact with open air, oxygen triggers a chemical reaction. The enzyme causes the polyphenols to oxidize. As a result of this reaction, new substances (quinones) are formed, which then turn into melanin-a natural dark pigment. It is this pigment that colors the juice brown. If the juice is strongly heated, the enzyme is completely destroyed and the juice stops darkening (this is done with commercially sold juices).

In most commercial and natural juices from different types of fruits, acidity varies within 5.0–9.0 g/L (0.5–0.9%) at a pH level of 3.3 to 4.0 (Popel et al., 2021).

According to the "Code of Practice of the European Fruit Juice Association" (AIJN Code of Practice), the range of standard titratable acidity values for authentic apple juice (expressed as citric or tartaric acid when determined to a specified pH value) is usually from 2.2 to 7.5 g/L (when titrated to pH 8.1, expressed as anhydrous citric acid) or from 5.0 to 8.5 g/L (expressed as tartaric acid to pH 7.0), depending on the apple variety and harvest season.

Expressed as malic acid, this range will be 2.30–7.85 g/L (when rounded to tenths-2.3–7.9 g/L).

As the research results show, the titratable acidity value in laboratory juice from late-October *Shihi Janı* apples (0.23 g/100 mL) corresponds to the minimum boundary for this indicator established in the AIJN Code of Practice. The titratable acidity values in juice from apples of the other varieties *Reinette Simirenko* (0.97 g/100 mL), *Starkrimson* (0.90 g/100 mL), *Reinette de Champagne* (0.90 g/100 mL), and *Sary Tursh* (0.90 g/100 mL) exceed the standardized indicators.

In natural laboratory direct-pressed juices from apples of the *Shihi Janı*, *Reinette Simirenko*, *Starkrimson*, *Reinette de Champagne*, and *Sary Tursh* varieties, the TSS indicator was 12.0; 13.0; 12.5; 12.5; and 10.5 °Brix, respectively.

According to the Code of Practice of the European Fruit Juice Association (AIJN Code of Practice), the minimum TSS content in natural apple juice (direct-pressed) must be at least 10.0 °Brix (at a relative density of 1.040).

Calculated at 10.0 °Brix, the malic-acid acidity of apples of the above-mentioned varieties is: *Shihi Janı* 0.19 (below the standard); *Reinette Simirenko* 0.75 (meets the standard); *Starkrimson* 0.72 (meets the standard); *Reinette de Champagne* 0.72 (meets the standard); *Sary Tursh* 0.86 (above the standard).

Apples are one of the most widespread fruits in the world. Improper storage leads to spoilage of up to 30–40% of the crop from fungal diseases and physiological disorders (Suravi et al., 2024; Ullah et al., 2025; Zaman et al., 2025).

Understanding fruit-aging processes helps extend the period of sale in regions where expensive equipment (CA/ULO) is unavailable. The consumer is concerned not only with appearance, but also with the content of vitamin C, sugars, organic acids, and antioxidants (Venkatesan & Muniyan, 2024; Zdulski et al., 2024).

The relevance of studying the influence of an uncontrolled storage environment on the biochemical indicators of technically mature apples is extremely high both for science and for the agro-industrial sector (Ferreira et al., 2024; Varivoda et al., 2022). Indeed, to prove the effectiveness of new technologies (modified atmosphere, 1-MCP treatment, biological preparations), scientists need a “control”—that is, precise data on what happens to an apple in an ordinary, uncontrolled environment. Without an accurate “control,” any claims about the effectiveness of new storage methods remain only assumptions (Filipowicz et al., 2026; Öztürk et al., 2026).

Data on the study of the influence of the storage environment on the biochemical indicators of Guba apples are fragmentary (Piriyeva & Hafizov, 2022); the results of this study address several important aspects concerning the degree of preservation of the main substances of the component composition under the simplest method of apple storage.

Harvested apples continue to live through internal respiration. Under ordinary (room or uncontrolled) conditions, this process proceeds quickly, consuming beneficial organic compounds and destroying vitamins.

Organic acids (primarily malic acid) are used by apple cells as a substrate for respiration as an energy source. During ripening and aging, apple enzymes actively oxidize organic compounds, converting them into water, carbon dioxide, and intermediate metabolic products. The longer apples are stored, the more their life cycles fade and acids break down, causing the flesh to taste less sour. At higher temperatures than in a refrigerator, metabolism proceeds faster, so acids break down more rapidly.

This study showed specific rates of decline in titratable acidity due to the natural consumption of organic acids in respiration and metabolic processes. After 5 months of storage under controlled natural ventilation, apple acidity decreased by a minimum of 24.24% (*Sary Tursh*) and a maximum of 83.96% (*Reinette Simirenko*).

The experiments also showed that under these conditions all chemical and enzymatic reactions accelerate, as a result of which vitamin C reserves are depleted several times faster than could occur at low temperature. Over five months of apple storage under controlled natural ventilation, the content of this vitamin, depending on the apple variety, decreased as follows: *Reinette de Champagne*-75.4%; *Reinette Simirenko*-56.68%; *Kandil Sinap*-76.16%; *Rosmarina Bianc*-53.51%; *Jir Gadzhi*-77.69%; and *Sary Tursh*-94.82% of its initial content at the very beginning of storage

6 CONCLUSIONS

The obtained data make it possible to draw the following conclusions:

- The final fruit size is determined not only by the rate of autumn growth but also by the mass basis established at the beginning of the summer period.

- The studied varieties have a high content of dry matter and soluble sugars and balanced acidity, which makes them valuable raw material for the fresh market, export, and processing.

- The concentration of total soluble solids in direct-pressed juices of local varieties (from 10.5 to 14.0 °Brix) exceeds the international standard for natural juices (10 °Brix). The highest values were recorded for the *Jir Gadzhi* variety.

- The *Sary Tursh* variety is characterized by increased acidity, and *Shihi Janı* by reduced acidity. The other studied varieties fully comply with international regulatory requirements.

- Autochthonous varieties (*Gara Tursh*, *Jir Gadzhi*) tend to concentrate dry matter, which makes them optimal for the production of pekmez and dried fruits. The maximum juice yield (more than 75%) is provided by the *Reinette Simirenko*, *Reinette de Champagne*, *Shihi Janı*, and *Sary Tursh* varieties.

- Five-month storage under controlled natural ventilation showed high keeping quality of the fruits, while the dynamics of changes in ascorbic acid content and acidity depended on varietal characteristics (the minimum decrease in vitamin C, 56.68%, was shown by *Reinette Simirenko* apples; the minimum decrease in acidity, 24.24%, by *Sary Tursh*).

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Figures

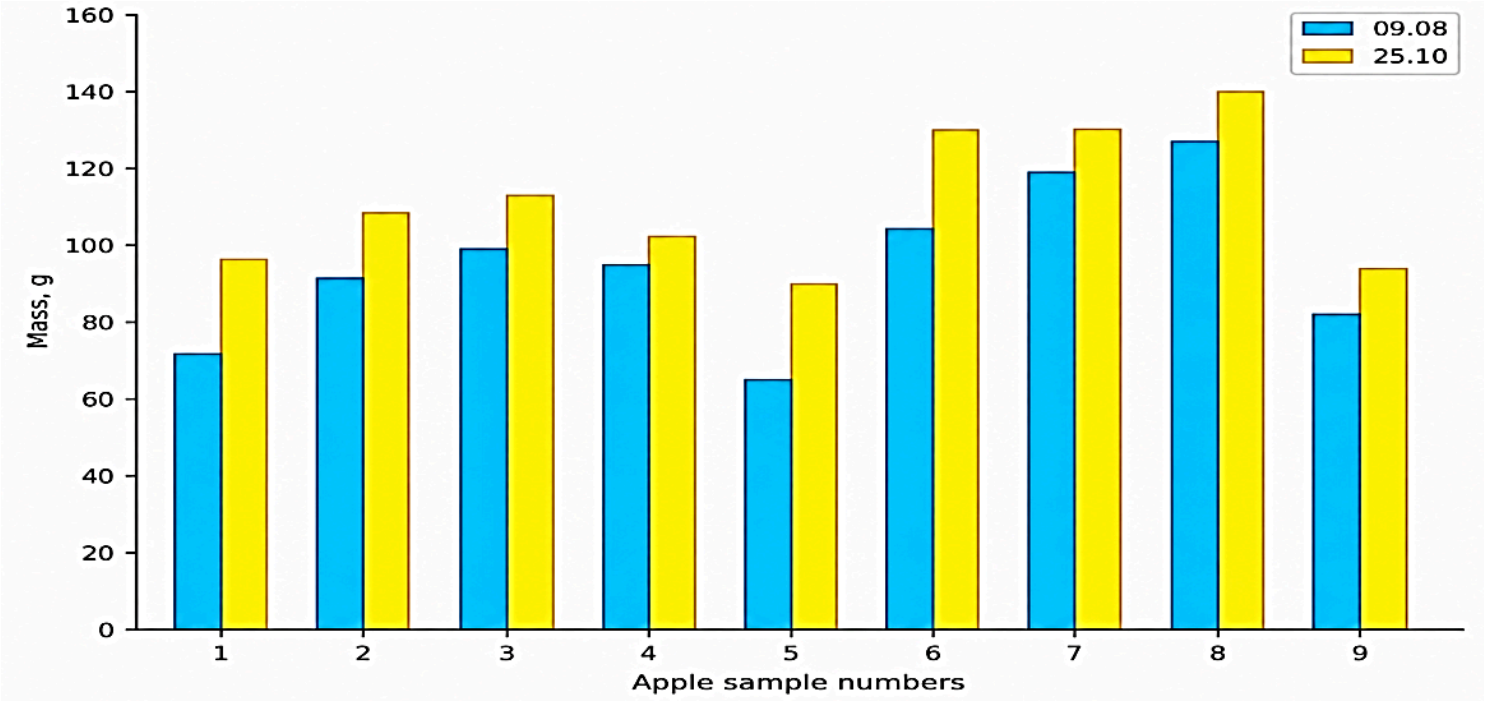


Figure 1

Weight change of an individual unripe and ripe apple at the end of the first decade of August and the middle of the last decade of October, depending on the variety: 1-*Gara Tursh*; 2-*Naila*; 3- *Golden Delicious*; 4-*Jir Gadzhi*; 5- *Reinette de Champagne*; 6- *Reinette Simirenko*; 7-*Starkrimson*; 8 -*Shihi Janı*; 9-*Sary Tursh*.

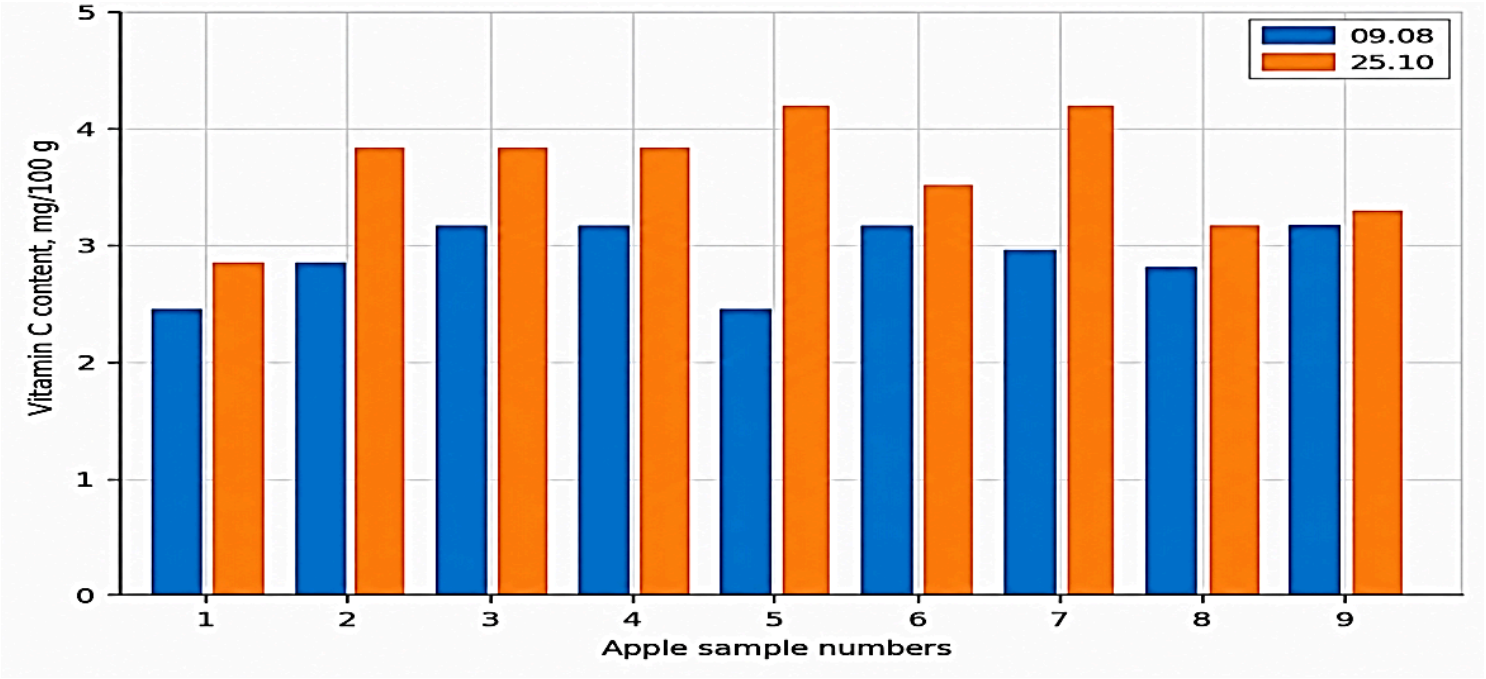


Figure 2

Vitamin C content in different samples of unripe and ripe apples from the end of the first decade of August and the middle of the last decade of October (Mg/100 g of raw weight): 1-*Gara Tursh*; 2-*Naila*; 3-*Golden Delicious*; 4-*Jir Gadzhi*; 5- *Reinette de Champagne*; 6- *Reinette Simirenko*; 7-*Starkrimson*; 8- *Shihi Janı*; 9-*Sary Tursh*.

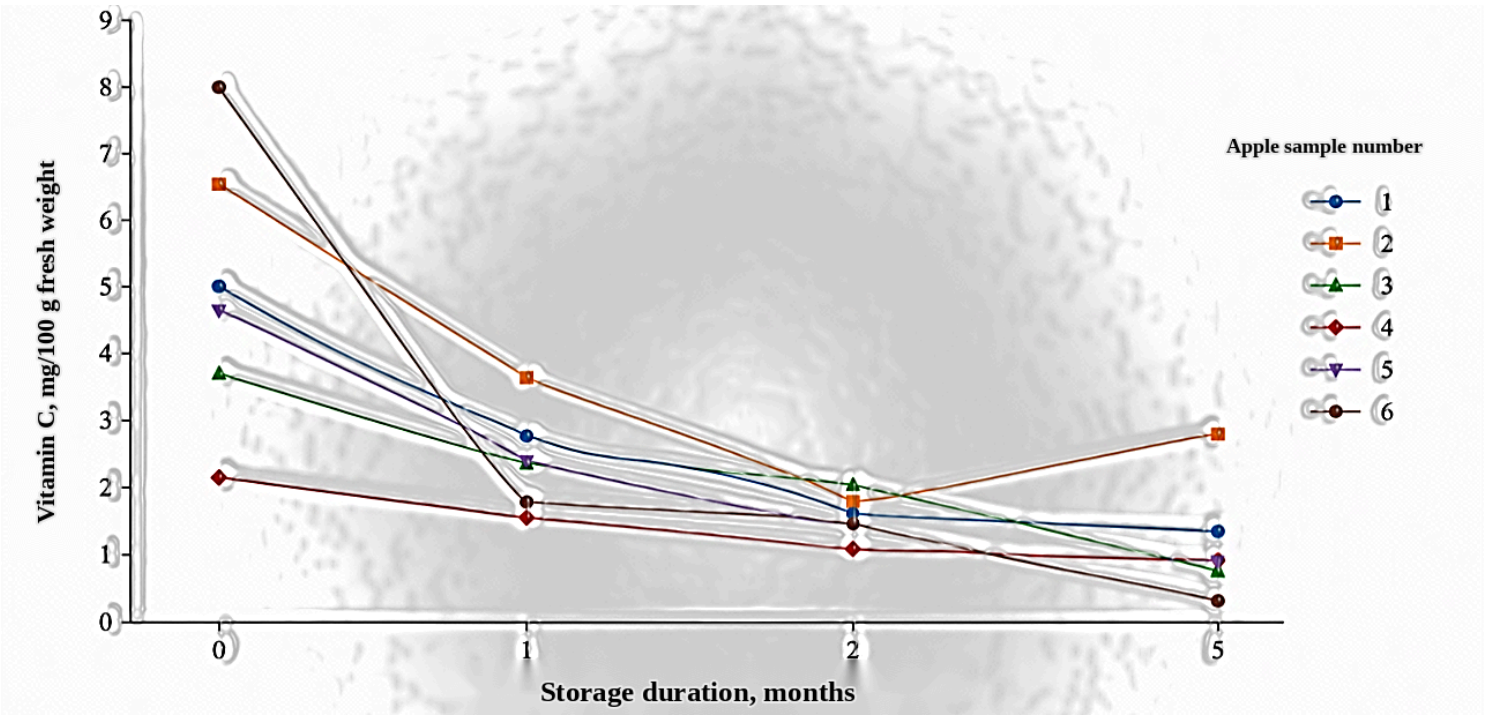


Figure 3

Dynamics of vitamin C in introduced and local apple varieties during storage in an uncontrolled environment (g/100 g fresh weight), mg/100 g: 1- Reinette de Champagne; 2- Reinette Simirenko; 3- Kandil Sinap; 4-Rosmarina Bianc; 5- Jyr Gadzhi; 6- Sary Tursh.

Supplementary Files

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- floatimage1.png