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Biodiversity in a Globalized Era: The Nutritional and Chemical Value of Traditional Apple and Pear Cultivars

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Research Article

Keywords: Apples and pears of Guba, ancient varieties, indigenous varieties, biochemical traits, shelf life

Posted Date: November 3rd, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11589488/v1

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Additional Declarations: The authors declare no competing interests.

Abstract

Conservation of genetic resources and assessment of economically valuable traits of traditional apple and pear varieties in the regions of their initial cultivation are priorities. This study examines the hidden chemistry of early introduced varieties and local autochthons.. The research was conducted in 2020–2022 following the chemical and technological variety-testing program approved by the Scientific Council of the Research Institute of Fruit and Tea Growing of the Ministry of Agriculture of Azerbaijan. The study spanned from fruit ripening in semi-intensive orchards near Zardabi village (Guba district) to the end of their post-harvest storage life. For biochemical analysis, a representative sample of 50 typical fruits per variety was collected from mature trees. For storage capacity trials, 100 kg of healthy fruits from each variety were used. The fruits were harvested at commercial maturity and stored under naturally ventilated conditions with a gradual temperature decline (from + 10...+12°C in October to + 2...+4°C in winter). The shelf life of late pear varieties was 1 month, while apples retained quality until spring. The ancient pear varieties and exhibited larger fruit size and higher acidity compared to the commercial and breeding reference varieties (, and , , ,), while the autochthonous variety showed high sucrose content. During five months of non-refrigerated post-harvest storage, the total dry matter content in local indigenous apple varieties and remained stable, indicating no dehydration and excellent juiciness retention. On the contrary, the dry matter content in apples of other ancient varieties increased by a maximum of 37.19% (in the variety). apples showed a minimal decrease in vitamin C by 56.68%, and Sary Tursch apples showed a minimal decrease in acidity by 24.24%. The data obtained scientifically substantiate the potential of ancient varieties for the production of authentic local products and modern breeding.

Introduction

Global climate change and the standardization of commercial horticulture are causing a rapid decline in the genetic diversity of fruit crops. Under current conditions, with the global market imposing its harsh rules, transnational commercial varieties have virtually displaced local classics [1, 2].

The modern fruit crop market is dominated by a limited number of global commercial apple varieties (Gala, Fuji, Pink Lady, etc.) and pear varieties (Conference, Abate Fetel, etc.).

By narrowing the range to a dozen global varieties, humanity is endangering food security. If a new aggressive virus or pest emerges that is adapted, for example, to Gala apples, orchards worldwide could be at risk.

FAO officially records that the main cause of crop genetic erosion worldwide is the replacement of local traditional varieties with commercial high-yielding or visually attractive hybrids as part of the standardization of industrial horticulture. The organization's experts emphasize that global climate change sharply increases the need for genetic diversity (to identify genes for resistance to drought, heat and new pests), while the industrial sector destroys that diversity [3]

A large interdisciplinary study describes the mechanisms of biodiversity loss in detail [4]. The authors demonstrate that the transition to large-scale single-variety production displaces locally adapted ecotypes (landraces). At the same time, climatic shifts destroy populations of wild relatives of fruit and berry crops (crop wild relatives), depriving breeding of its natural reserve for developing climate-resilient varieties.

The main reasons why “glossy” new varieties win the competition, and the consequences of this, are as follows:

- - Modern varieties withstand months of storage in controlled-atmosphere chambers and shipment to other continents without losing their marketable appearance. Old varieties are often too delicate, bruise during transport and quickly shrivel.
- - Buyers “choose with their eyes.” Large, perfectly round, bright red or glossy green apples without blemishes sell better than plain-looking or asymmetrical old varieties.
- - New hybrids are developed for intensive orchards (dwarfing rootstocks, ease of mechanized pruning and harvesting). They begin bearing fruit in year 2–3, whereas old trees often required 7–10 years.
- - Breeders deliberately incorporate immunity to scab, powdery mildew and other common pathogens into new varieties.

But what do we lose along with old varieties?

Many old varieties have a unique aroma, tartness or spicy notes that are entirely absent from “plastic” shop-bought apples bred solely for sweetness.

Old varieties are an invaluable genetic bank.

Old varieties have a rich biochemical composition (high tannin content).

Old varieties are ideal for processing (cider, pectin, drying). Some varieties are ideal only for brining, others for pies (they do not turn to mush during baking), and still others for cider or jam. New all-purpose varieties are often inferior in culinary use.

Old varieties have high natural immunity; new varieties require regular chemical protection.

Is there hope for revival?

Today, a countertrend is growing worldwide: demand for authenticity and local products. Producers of traditional cider and organic juices are showing renewed interest in old varieties. Amateur gardeners increasingly seek saplings “from childhood” at nurseries, preserving them on their plots. Scientists and enthusiasts are establishing pomological orchards to preserve the gene pool for future generations of breeders.

Traditional pear and apple varieties introduced early into the Guba-Khachmaz zone, together with varieties developed through folk selection and historically grown there, constitute a unique gene pool with high adaptability to local climatic conditions, resistance to pathogens, unique flavor qualities and a distinctive biochemical profile.

Changes in the biochemical parameters of fruits during ripening and subsequent storage directly affect the yield of finished products, their sensory properties and the retention of beneficial substances [5, 6].

This creates the need for an accurate assessment of the raw material value of fruits at different stages of their technological development.

They can be used for: recording the genetic and biochemical traits of rare varieties for future generations; identifying marker genes responsible for high acidity, flesh firmness or disease resistance; analyzing how old varieties survived for decades without modern chemicals and pesticides; enriching fundamental science with information on metabolic variability in cultivated plants; creating unique local products (authentic wines, vinegars, juices) associated with a particular region.

The main objective of the study is to identify and compare patterns of changes in the chemical composition of apples and pears of autochthonous and traditional introduced breeding at the stages of maturation and post-harvest storage in order to assess their technological potential and shelf life.

MATERIALS AND METHODS

The work was carried out in 2020–2022 in accordance with the Methodology of chemical and technological variety testing approved by the Scientific Council of the Research Institute of Horticulture and Tea Growing of the Ministry of Agriculture of the Republic of Azerbaijan. This methodology was developed taking into account the key provisions of the “Program and methodology of variety study of fruit, berry and nut crops” All-Russian Research Institute of Fruit Crop Breeding [7].

2.1 Objects of research

The object of the study was pears and apples of traditional early introduced and local autochthonous varieties.

The pears were of the ancient varieties *Cure*, *Beurré Bosk* and *Jir Nadiri*.

The commercially sought-after *Williams* and *Clapp's Favorite* varieties, as well as varieties from the *Latifa*, *Bagban*, *Al Yanag* and *Gulshen* Research Institute of Fruit and Tea Growing, were selected as comparison varieties.

Jir Nadiri is an endemic ecotype bred by folk breeding. Its small fruits have outstanding taste qualities: high sugar content and intense varietal aroma.

Cure, *Beurré Bosk*, *Williams* and *Clapp's Favorite*: although these four varieties are historical (they are more than 150–250 years old), their status in modern horticulture varies. *Cure* (*Winter Williams*) is an ancient winter variety that accidentally appeared in France back in 1760. It used to be the basis of commercial gardens in the south of the USSR, but is now rapidly disappearing.

Beurré Bosk (*Beurré Alexander*) is a famous autumn variety bred in France at the end of the 18th century. Due to its high thermophilicity, low winter hardiness and high susceptibility to diseases, it is less and less planted for commercial purposes and is gradually becoming a rare collector's variety.

Williams (*Williams' Bon Chrétien*, *Bartlett*) - a variety bred at the end of the XVIII century, despite its age, does not disappear from gardens. It remains the world standard for summer pears and the main variety for processing (purees, juices, canning).

Clapp's Favorite is a summer variety bred in 1860 in the USA by breeder Thaddeus Clapp. It is still popular in private gardens and farms because of its exceptional hardiness, unpretentiousness and excellent fruit flavor, so it cannot be called “endangered".

The endangered historical varieties on this list primarily include *Cure*, *Beurré Bosk* and *Jir Nadiri*.

The apples were of local autochthonous and early 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 range *Golden Delicious* and *Starkrimson* and new varieties of breeding varieties *Naila* and *Azerbaijan* were used as comparison varieties.

The fruits for analysis were harvested at the stage of optimal harvest maturity, which occurred for the *Azerbaijan* variety in mid-September, for the *Kandil Sinab* and *Rosmarina Bianc* varieties in early October, and for other studied varieties in late October.

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

Starkrimson is a bud mutation of the variety *Starking Delicious*, bred in 1952. This is a popular American variety of the “spur” type (with a compact crown). It remains a high-yielding commercial variety in the southern regions of Russia and the CIS countries. Its fruits are valued for their rich dark ruby color, excellent shelf life and transportability, so the demand for seedlings and fruits remains consistently high.

They can be considered classic varieties “with a history”, but the status of “endangered” does not apply to them. From the point of view of pomology (the science of varieties), their status differs from that of truly ancient folk varieties.

Golden Delicious and *Starkrimson* are world 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. The really old, traditional varieties (and those that do partially disappear from commercial circulation) have been created for centuries, have a sprawling crown and are often unsuitable for modern intensive gardens.

2.2 Subject and principles of the study

The subject of the study was the scientific and methodological substantiation of the dynamics of the quality indicators of pear and apple fruits, starting from the time of fruit ripening and until the end of their allotted shelf life after harvest.

A representative sample of 50 typical fruits of each variety was collected from mature trees for biochemical analyses.

Apple 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.

100 kg of healthy fruits of each variety were used to test the storage capacity. The fruits were harvested during the removable maturity period and stored in natural ventilation conditions with a gradual decrease in temperature (from + 10...+12°C in October to + 2...+4°C in winter). The shelf life of late varieties of pears was 1 month, while apples retained their quality until spring.

2.3 Location and type of apple and pear orchard

When laying apple orchards, the distance between rows and seedlings depends on the strength of the rootstock growth: on strong-growing rootstocks, the planting pattern is 6–7 × 4–5 m, on medium-strong rootstocks – 5–6 × 3–4 m, on semi-dwarf rootstocks – 4–5 × 2–3 m, and on dwarf rootstocks – 3–4 × 1–2 m.

Strong-growing rootstocks of apple trees are grown from seeds of wild forest apple trees or hardy varieties. These include seedlings of wild apple trees of *Antonovka* and *Anise* varieties, as well as clone varieties MM 104, A2, etc. They form the basis for large trees with a height of more than 4–5 meters with powerful roots, durability up to 40–50 years and high resistance to drought and frost.

An apple orchard with a 5×4 m planting scheme on a medium-sized rootstock with a free or oblique palmetto crown belongs to a semi-intensive or moderately intensive industrial type of orchard. In such gardens, the planting density is 500 trees per hectare; they belong to the category of moderately dense plantings. The type of rootstock is medium-sized (clonal, for example, 54–118, MM-106), and the crown shape is a flat palmette (Italian or oblique), which requires the installation of a lightweight trellis and regular shaping pruning in one plane. Such a garden occupies an intermediate position between traditional extensive gardens (on strong-growing seedling rootstocks with free crowns) and modern

intensive and high-intensity (dwarf) gardens. In modern intensive gardens with a trellised “thin spindle”, the planting density ranges from 1250–2500 trees per hectare and above.

The main differences in the planting schemes of apple and pear trees are as follows.

The apple tree.

- • Dwarf and semi-dwarf varieties: require less space, the standard scheme is 2.5 × 3 m or 3 × 4 m.
- • Medium-sized varieties: planted according to the 4 × 4 m scheme.
- • Low-growing varieties: usually require about 4 × 6 m.

Pear.

• Large-growing varieties with a voluminous crown require more space and light, so the distance between them in a row is increased to 5–6 m, and between rows - up to 4–5 m (for example, 5 × 3 m for small and 6 × 4 m for medium-sized / large pears).

The Guba-Khachmaz region is located in the northeast of Azerbaijan and consists of foothill and lowland zones with common gray-brown and fertile meadow-brown soils, respectively [8].

In this study, pears and apples were taken from semi-intensive garden plantings near the village of Zardabi, which is 10 km less away from the Caspian Sea than from the Guba regional center. This village has a special microclimate that makes the local fruits exceptionally juicy and sweet. The terrain here is flat, the climate is milder than in the foothills, and the soils are more fertile. The average annual air temperature here is about 12°C. Precipitation remains in the range of 340–350 mm per year, while the influence of northerly winds is felt.

2.4 Sampling of the average sample and samples for chemical analyses

When selecting an average sample of fruits for chemical analyses, the rules are followed to ensure the objectivity and representativeness of the results. To make an average sample of 50 fruits, they are harvested evenly from 5–10 trees (usually from at least 5 trees of the same pomological variety). The trees are selected diagonally or staggered. You can not take fruits only from the outermost or only from diseased trees.

5–10 fruits are taken from each tree from different parts of the crown (inner and outer), from all four sides of the world (north, south, east, west) and from different tiers (upper, middle, lower). The fruits should be of different sizes (typical for this variety).

An average sample is formed from the initial average sample (50 fruits):

For analysis, 10–20 fruits (or about 1–2 kg) are isolated, which most accurately reflect the characteristics of the entire batch.

In the selection method (quartering), all 50 fruits are laid out in a row according to size or degree of maturity, after which every second, third or fourth fruit is taken (mechanical selection method) until the required amount is reached (for example, 15 pieces).

The sample for analysis is the exact amount of crushed material that will be directly used in a chemical reaction (usually from 5 to 50 grams) - prepared as follows.

- -Fruits selected for analysis (10–20 pcs.) are washed, dried with filter paper, stems and seed chambers are removed (if only the pulp is analyzed);
- - Each fruit is cut along the axis into 2, 4 or 8 equal slices.
- - One or two opposite slices are taken from each fruit.
- - These slices are quickly ground (on a plastic grater or in a blender) until a homogeneous puree (mash). It is important to do this quickly to avoid oxidation and loss of vitamins.
- - The resulting mass is thoroughly mixed.
- - A weight is taken from freshly prepared and well-mixed mashed potatoes on analytical or precision scales with an accuracy of 0.01 g or 0.001 g.
- - The size of the attachment depends on the method of specific analysis:
- • To determine sugars or titrated acidity, 25–50 g of pulp is usually taken.
- • For the determination of dry matter (by drying) -3-5 g.
- • For the determination of vitamin C -10-20 g.

The suspension is taken from different places in the container with mashed potatoes, avoiding settling of the juice. The crushed mass should not be stored, the analysis should begin immediately after grinding.

2.5 Methods of chemical composition assessment

Soluble dry substances (TSS) - according to ISO 2173 – 2013 (ISO 2173 – 2013, 2019). The concentration is measured using digital refractometers (by refraction of light) in grams per 100 g or in degrees on the Brix scale (°Bx); 1 degree on the Brix scale is equal to 1 gram of sucrose in 100 grams of solution (at a standard temperature of 20 ° C).

The Brix index shows the concentration of substances in the squeezed cell juice, and not in the mass of a whole apple. When researchers or agronomists write, for example, “the content of soluble solids in apples of the X variety is 12° on the Brix scale,” this is a professional abbreviation. This means: “the cellular juice extracted from this apple contains 12 grams of soluble substances per 100 grams of juice.”

Dry substances (DM) are measured by thermogravimetric method in accordance with GOST 33977 – 2019.

Ascorbic acid is obtained by the iodometric method according to GOST 24556-89 (GOST 24556-89, 2003).;

Sugars (reducing sugar, sucrose and total sugar) according to the Bertrand method (GOST 8756.13-87, 2010).

Titrated acidity – according to ISO 750–2013, 2018.

2.6 Processing of primary data

The determination of each physico-chemical indicator was carried out in three parallel repetitions. The total data for three years of research (n = 9) for each parameter was subjected to statistical analysis in the Statistica 10.0 package. Arithmetic averages and their confidence intervals were calculated.

RATIONALE FOR THE CHOSEN RESEARCH DIRECTION AND THEORETICAL CONSIDERATIONS

Traditional heritage varieties are better adapted to local growing conditions and are often more resistant to pests and diseases, requiring fewer chemicals, which makes them a more sustainable option for apple production. Economically, traditional pear and apple varieties offer advantages for small-scale and organic farmers. These varieties are generally cheaper to grow and maintain because they do not require the same level of chemical inputs. Moreover, high concentrations of bioactive compounds and superior sensory properties make them attractive for producing high-quality artisanal apple products, such as organic apple cider and preserved fruit. These products can command higher prices in markets where consumers are willing to pay more for natural, minimally processed products.

Varieties developed through folk selection (or local, indigenous varieties) are plants that arose through many years of selection by peasants and amateur gardeners, rather than in research institutes. The names of their creators have been lost over the centuries, while the plants themselves were passed down from generation to generation in a particular locality. People selected the best seeds or saplings for flavor, yield and resilience after harsh winters or droughts. These varieties are ideally adapted to the local climate and soils and are resistant to local diseases. They constitute valuable raw materials for producing functional foods, juices, ciders and jelly products.

However, conserving and successfully integrating these varieties into modern production and processing is impossible without a detailed understanding of their behavior at different stages of maturity and systematic data on their technological potential.

Changes in the biochemical parameters of fruits during ripening and subsequent storage directly affect the yield of finished products, their sensory properties and the retention of beneficial substances.

This creates a need for an accurate assessment of the raw material value of fruits at different stages of their technological condition.

RESULTS AND DISCUSSION

The results obtained are divided into two blocks: the 1st concerns changes in the chemical composition of pears depending on the variety and degree of maturity and the time of post-harvest storage under unregulated conditions; the 2nd concerns quantitative changes in key nutrients in apples during their post-harvest ripening.

4.1. Chemical composition of pears: how it changes with variety, degree of maturity and duration of postharvest ripening

The chemical composition of pears at harvest (technical) maturity develops through the complex coordination of the synthesis and breakdown of organic substances and is balanced to give the fruit a “margin of resilience” for logistics. It contains the full potential for the subsequent conversion of starch and pectins into sugars and soluble fibers, which occurs during storage before consumption [9, 10]. Technically mature pears accumulate the maximum amount of nutrients and are ready for harvest for subsequent ripening, transport or processing.

From the data in the Table 1 is visible that *Williams*, *Bagban*, *and Jir Nadiri* pears gain full weight in the first days of August, while *Beurré Bosk* pears gain full weight by the end of the second decade of August.

After that, they are left on the tree for another week or two to improve sensory qualities, while this practically does not affect the weight of the individual fruit and it remains at the same initial level.

On the contrary, *Cure* and *Latifa* pears at this time continue to gain weight even after the end of summer until the very end of September, while the speed of this process in the autumn period is much lower than the speed of this process in July and August.

Cure pears (200 ± 35 g) are significantly or slightly larger during harvest than pears of the world-famous commercial varieties *Williams* (103 ± 20 g) and *Clapp's Favorite* (196 ± 28 g). The weight of an individual fruit in other studied varieties was: *Latifa* – 200 ± 38 g, *Beurré Bosk* – 158 ± 30 g, *Bagban* – 133 ± 18 g and *Jir Nadiri* – 51 ± 4 g.

Table 1
Changes in the chemical composition of pears, starting from the first decade of July and until harvest time (% of the crude weight).

Pear varieties	Date (day, month)	TSS	DM	Reducing sugar	Sucrose	Acidity (as malic acid)
Newcomers and local outgoing ancient varieties						
Cure	24.07–03.08	10,3 ± 0,3	20,3 ± 0,6	5,15 ± 0,15	1,53 ± 0.05	0,71 ± 0,05
	07.08–17.08	11,0 ± 0,3	18,0 ± 0,5	5,66 ± 0,15	1,59 ± 0.06	0,61 ± 0,04
	28.08–07.09	12,0 ± 0,4	17,7 ± 0,5	6,01 ± 0,16	1,71 ± 0.05	0,53 ± 0,03
	15.09–25.09	13,3 ± 0,4	17,2 ± 0,5	7,39 ± 0,19	1,83 ± 0,06	0,48 ± 0,03
Clapp's Favorite	24.07–03.08	10,8 ± 0,3	14,8 ± 0,4	5,94 ± 0,14	0,78 ± 0,04	0,69 ± 0,04
	07.08–17.08	14,2 ± 0,4	18,0 ± 0,5	8,09 ± 0,20	0,78 ± 0,04	-
	28.08–07.09	-	-	-	-	-
	15.09–25.09	-	-	-	-	-
Jir Nadiri	24.07–03.08	14,2 ± 0,4	19,9 ± 0,5	8,70 ± 0,19	0,76 ± 0,03	0,28 ± 0,03
	07.08–17.08	15,8 ± 0,5	21,5 ± 0,7	6,80 ± 0,18	4,11 ± 0,10	0,24 ± 0,03
	28.08–07.09	-	-	-	-	-
	15.09–25.09	-	-	-	-	-
Global-commercial varieties						
Williams	24.07–03.08	12,2 ± 0,3	17,5 ± 0,5	6,35 ± 0,17	0,87 ± 0,04	0,83 ± 0,06
	07.08–17.08	14,2 ± 0,4	20,0 ± 0,6	7,12 ± 0,20	0,97 ± 0,05	0,81 ± 0,06
	28.08–07.09	-	-	-	-	-

Pear varieties	Date (day, month)	TSS	DM	Reducing sugar	Sucrose	Acidity (as malic acid)
	15.09–25.09	-	-	-	-	-
Beurré Bosk	24.07–03.08	11,7 ± 0,3	17,5 ± 0,5	5,75 ± 0,15	0,37 ± 0,03	0,69 ± 0,04
	07.08–17.08	12,3 ± 0,3	18,2 ± 0,5	6,17 ± 0,16	0,70 ± 0,03	0,61 ± 0.04
	28.08–07.09	14,3 ± 0,4	20,0 ± 0,6	7,30 ± 0,20	0,99 ± 0,05	0,51 ± 0,03
	15.09–25.09	17,1 ± 0,5	21.3 ± 0,7	9,87 ± 0,25	1,12 ± 0,06	0,37 ± 0,03
New varieties of breeding of the Research Institute of Fruit and Tea Growing						
Latifa	24.07–03.08	11,0 ± 0,3	22,0 ± 0,8	3,90 ± 0,13	1,31 ± 0,07	0,43 ± 0,03
	07.08–17.08	11,8 ± 0,3	21,3 ± 0,6	3,90 ± 0,12	1,40 ± 0,08	0,37 ± 0,03
	28.08–07.09	12,3 ± 0,3	20,3 ± 0,6	3,90 ± 0,13	2,30 ± 0,10	0,32 ± 0,03
	15.09–25.09	12,4 ± 0,3	18,7 ± 0,5	3,90 ± 0,14	3,95 ± 0,10	0,25 ± 0,02
Bagban	24.07–03.08	14,2 ± 0,4	15,5 ± 0,4	7,91 ± 0,17	0,84 ± 0,04	0,85 ± 0,07
	07.08–17.08	15,2 ± 0,4	17,7 ± 0,4	7,84 ± 0,15	0,97 ± 0,05	0,81 ± 0,06
	28.08–07.09	-	-	-	-	-
	15.09–25.09	-	-	-	-	-
P - value		≤ 0,05	≤ 0,05	≤ 0,05	≤ 0,05	≤ 0,05

The data in Table 1 shows how the biochemical composition of the pears of these seven varieties changed from the end of July to harvest time.

It can be seen from them that, regardless of the variety, the content of soluble solids (TSS) in pears gradually increased during the period under review.

According to the dynamics of dry matter (DM), the same grades are divided into two opposite groups.

In the pears of the first main varietal group (*Beurré Bosk*, *Williams*, *Bagban*, *Jir Nadiri* and *Clapp's Favorite*), the DM content gradually increased as they matured; in the pears of the other group (Cure, Latifa), on the contrary, decreased.

It is known that carbohydrates form the basis of the dry matter of pears.

By technical maturity, sugars accumulate intensively.

According to the data in the above-mentioned table, by the time of removable maturity, the total sugar content (inverse sugar and sucrose) remained almost the same as in late July and early August, or increased, but slightly. For early varieties of *Wilyams* and *Bagban* pears, this indicator increased by only 0.06%, *Jir Nadiri* – 1.45%, *Clapp's Favorite* – 2.17%.

Later varieties showed a more significant increase in total sugar content. Starting from the end of July - beginning of August and ending with the onset of removable maturity, the total sugar content in *Cure* pears increased by 2.54%, *Latifa* – 2.64%, to 7.85; *Beurré Bosk* – 4.87%.

Other varietal differences were as follows.

In some varieties (*Latifa*, *Bagban*, *Jir Nadiri*), the increase in the concentration of reducing sugar was slower than the increase in the concentration of total sugar. On the contrary, in the *Clapp's Favorite* variety, the increase in total sugar concentration was mainly due to reducing sugar, rather than sucrose. Whereas in the Cure and *Williams* varieties, the total sugar content increased almost equally, both due to reducing sugar and sucrose.

Unlike apples, pears contain mostly fructose, followed by glucose and sucrose. The high fructose content gives pears a sweet taste, even if their total sugar content is relatively low. Sorbitol gives this fruit additional sweetness and dietary properties.

Pears have low acidity compared to other seed-bearing fruit crops.

Table 1 shows that at the end of July, the acidity of pears ranged from 0.28 ± 0.03% (*Jir Nadiri*) to 0.88 ± 0.07% (*Bagban*), and during their removable maturity - from 0.24 ± 0.03 (*Jir Nadiri*) up to 0.81 ± 0.06% (*Williams*, *Bagban*). The pears of removable maturity *Cure* and other varieties have significantly lower acidity than those of *Williams* and *Bagban* pears.

Malic acid is the main acid in pears, while citric and succinic acids are present in much smaller amounts. The low acid content combined with the high fructose content ensures a high sugar-acid ratio typical of pears (sweet taste with barely noticeable astringency).

Technically mature pears are still dominated by protopectin, which binds skin and pulp cells. As a result, the fruits remain firm and resistant to mechanical damage during harvesting and transportation. The conversion of protopectin into soluble pectin is just beginning at this stage. Its intensive hydrolysis

(dilution of the intercellular substance), which softens the pulp and gives it an oily or melting texture, occurs later, during the transition to food ripeness.

By the time of technical maturity, the process of starch hydrolysis to form soluble simple sugars is in full swing, but has not yet been completed. A significant portion of starch is broken down into soluble sugars later, during subsequent storage and maturation.

The rate of starch breakdown in pears can be judged by the rate of increase in their sugar content.

In the Table 2 shows how the sugar content of pears has changed over the entire period of their normal post-harvest storage, from October 20 to November 20.

Table 2
Changes in the chemical composition of late-ripening pears during their post-harvest storage for one month under natural ventilation conditions at a temperature of + 10...+12°C (% by crude weight).

Pear variety	Date (month, day)	TSS	DM	Reducing sugar	Sucrose	Acidity (as malic acid)
Latifa	10.20	12,1 ± 0,2	17,7 ± 0,2	4,17 ± 0,05	3,27 ± 0,04	0,20 ± 0,01
	11.01	13,0 ± 0,2	18,8 ± 0,3	5,47 ± 0,09	2,83 ± 0,05	0,19 ± 0,01
	11.20	14,5 ± 0,3	18,9 ± 0,3	6,15 ± 0,10	2,18 ± 0,03	0,18 ± 0,01
Al Yanag	10.20	12,3 ± 0,2	18,8 ± 0,3	6,60 ± 0,11	0,17 ± 0,01	0,40 ± 0,02
	11.01	15,0 ± 0,3	18,6 ± 0,3	7,09 ± 0,12	0,20 ± 0,01	0,37 ± 0,02
	11.20	15,5 ± 0,3	18,5 ± 0,3	7,65 ± 0,13	0,23 ± 0,01	0,33 ± 0,02
Gulshen	10.20	11,8 ± 0,2	17,5 ± 0,2	6,97 ± 0,12	0,78 ± 0,02	0,56 ± 0,03
	11.01	13,0 ± 0,2	19,0 ± 0,4	8,52 ± 0,18	0,53 ± 0,02	0,52 ± 0,03
	11.20	14,0 ± 0,2	20,1 ± 0,4	8,52 ± 0,17	0,51 ± 0,02	0,43 ± 0,02
Cure	10.20	12,0 ± 0,2	18,6 ± 0,3	6,68 ± 0,11	0,14 ± 0,01	0,53 ± 0,03
	11.01	13,3 ± 0,2	18,4 ± 0,3	8,29 ± 0,14	0,24 ± 0,01	0,50 ± 0,03
	11.20	13,5 ± 0,2	18,0 ± 0,3	8,47 ± 0,14	0,37 ± 0,01	0,47 ± 0,03
P - value		≤ 0,05	≤ 0,05	≤ 0,05	≤ 0,05	

Her data indicate that during one month of storage, the total sugar content (reducing sugar + sucrose) in pears increased significantly: in *Latifa* pears - from 7.44±% to 8.33±%; *Al Yanag* – 6.77±% ...7.88±%; *Gulshen* – 7.75±% ...9.03±%; *Cure* – 6.82±% ... 8.84 ±%.

Figure 2 - Changes in the vitamin C content in late-ripening pears during their post-harvest storage for one month under natural ventilation at a temperature of + 10...+12°C.

As can be seen from it, pears contained relatively little of this vitamin at the very beginning of storage (*Latifa* 3.53 mg%; *Al Yanag* 3.51 mg%; *Gulshen* 4.25 mg%; *Cure* 4.51 mg%), and even less by the end of

the storage period: Latifa 1.76 ± mg%; *Al Yanag* 1.76 ± mg%; *Gulshen* 1.52 ± mg%; *Cure* 1.548 ± mg%.

This is because as the fruits reach nutritional ripeness and soften, some of the vitamin C is broken down by enzymes (ascorbate oxidase) and oxidative processes. The concentration of ascorbic acid gradually decreases although the flesh becomes more balanced, sweet and safe for digestion (the presence of tannins and stony cells is barely noticeable). Fruits maximize their flavor, as the synthesis of esters (especially methyl and ethyl esters of decadienoic acid), which give them their characteristic “pear” flavor, is in its final stages.

Thus, the early introduced *Cure* variety (200 ± 35 g) is larger than the pears of the world-famous commercial varieties *Williams* (103 ± 20 g) and *Clapp's Favorite* (196 ± 28 g), and the local autochthonous variety *Jir Nadiri* differs from other studied pear varieties by a very high percentage of sucrose.

4.2. Physico-chemical and technological properties of apples of various stages of technical and biological ripeness.

4.2.1. The chemical composition of apples of different varieties and different degrees of maturity.

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

The difference in weight between an unripe and ripe apple indicates the strength of the “influx” of nutrients. If the weight of the fruit on the tree has stopped increasing, this is one of the signs that the crop is ripe.

Figure 3 - The weight of one individual fruit at the end of the first decade of August and the middle of the last decade of October for different varieties of apples: 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*.

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*).

The weight of the fruit is a varietal characteristic. Various 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).

The fruit mass determines its future fate: large and medium-sized apples go to the market fresh (they cost more), and small the fruits are sent for processing (in juice, mashed potatoes, cider).

Fruits of the same variety that are too large are often stored worse, because their flesh is more friable and prone to physiological disorders (for example, the formation of a bitter stone). The optimal average weight guarantees a longer shelf life.

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. 4, the concentration of this vitamin in apples of all the above varieties increased slightly over the period from 09.08 to 25.10 (mg%): *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 Jani – 2.82 ...3.17; Sary Tursh – 3.17... 3.27.

As can be seen from these figures, the leading variety in terms of 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%).

During the period of removable maturity at the end of October, the vitamin C content was the highest in apples of *Reinette de Champagne* varieties (4.22 ± 0.25 mg/100 g) and *Starkrimson* (4.22 ± 0.10 mg/100 g).

Let's return to the *Azerbaijan* variety: in that part of the apples of this variety, which continued to remain on the tree as a result of insufficiently complete harvesting, the vitamin C content increased from 3.95 ±

0.15 to 4.58 ± 0.20 mg% over the same period.

Table 3 presents the quantitative content of dry matter and some key nutrients in unripe and ripe apples by variety.

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

1-Endangered early introduced (*Reinette de Champagne* and *Reinette Simirenko*) and local autochthonous (Gara Tursh, Sary Tursh, Jir Gadzhi and Shikhi Dzhany) varieties; 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* breeding (*Naila*).

Table 3 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%), and the maximum for *Gara Tursh* (from 8.4 ± 0.3% to 11.5 ± 0.3%).

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

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% to 10.50%, or by 21.4%; *Reinette de Champagne* - from 6.44% 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%; 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% (*Shihi Janı*) – 0.92 ± 0.05% (*Reinette Simirenko*).

Table 3
Changes in the content of some key nutrients in apples of local and introduced varieties depending on the degree of maturity (% fresh weight).

Apple variety name	Date (day, month)	DM	TSS	Reducing sugar	Sucrose	Acidity (as malic acid)
Endangered early 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).

4.2.2. *Quantitative dynamics of the main nutrients in apples during their post-harvest storage.*

Apples are among the most widely produced fruits in the world. Improper storage causes losses of up to 30–40% of the crop through fungal diseases and physiological disorders [11, 12, 13].

Understanding fruit senescence helps extend marketable life in regions without expensive equipment (CA/ULO). Consumers care not only about appearance but also about the content of vitamin C, sugars, organic acids and antioxidants [14, 15].

Studying the effects of uncontrolled storage conditions on the biochemical parameters of technically mature apples is highly relevant to both science and the agro-industrial sector [16], [17]. To demonstrate the effectiveness of new technologies (modified atmosphere, 1-MCP treatment, biological preparations), scientists need a “control”: 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 mere assumptions [18, 19].

Given that information on the influence of the storage environment on the biochemical parameters of technically mature apples grown in Guba District, Azerbaijan, is fragmentary [20], these experiments aimed to show the extent of biochemical changes in apples from Guba during postharvest storage under uncontrolled conditions.

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

Figure 5 - Changes in the vitamin C content in apples of late varieties during their post-harvest storage for five months under natural ventilation conditions with a gradual decrease in temperature from + 10...+12°C in October-November to + 2...+4°C in winter.

Figure 5 shows the change in vitamin C content in apples during post-harvest storage under the conditions of our experiment.

As it can be seen from it, the content of this vitamin in apple varieties has significantly decreased already in the first month of their storage. By the end of storage, the vitamin C content in all samples was significantly lower than the baseline level.

Reinette de Champagne apples initially contained 5.00 mg% of this vitamin, after 5 months of storage its content was only 1.23 mg%; *Reinette Simirenko* – 6.51 ... 2.82 mg%; *Kandil Sinap* – 3.69 ... 0.88 mg%; *Rosmarina Bianc* – 2.28 ... 1.06 mg%; *Jir Gadzhi* – 4.75 ... 1.06 mg/%; and *Sary Tursh* – 7.92 ... 0.41 mg%.

The percentage decrease in different varieties of apples was: *Reinette de Champagne* – 75.4; *Reinette Simirenko* – 56.68; *Kandil Sinap* – 76.16%; *Rosmarina Bianc* – 53.51%; *Jir Gadzhi* – 77.69%; *Sare Tursh* – 94.82.

The maximum decrease in the quantitative content of vitamin C was noted for *Kandil Sinap* apples (76.16%), the minimum - *Rosmarina Bianc* (53.51%) with the lowest the content of this vitamin at the beginning of storage.

Table 4
Changes in the chemical composition of apples of late varieties during their post-harvest storage for five months under natural ventilation conditions with a gradual decrease in temperature from + 10...+12 ° C in October-November to + 2...+4°C in winter.

Apple variety	Stages (months)	TSS	DM	Reducing sugar	Sucrose	Acidity (as malic acid)
Newcomers outgoing ancient varieties						
Reinette de Champagne	0	11,0	12,1	6,13	1,17	0,90
	1	11,5	12.4	7,44	1.33	0,87
	2	11,5	16,3	7,76	1,70	0,67
	5	11,5	16,6	8,31	1,75	0,57
Reinette Simirenko	0	10,5	13,3	6,97	0,69	1,06
	1	11,7	13,5	6,86	2,05	0.72
	2	11,5	13,8	7,07	1,02	0,50
	5	11,5	14,5	7,61	2,03	0,17
Kandil Sinap	0	12,5	16,6	7,15	0,69	0,40
	1	12,5	14,2	8,09	1,64	0,31
	2	12,0	14,9	9,38	0,80	0,20
	5	12,5	17,0	9,68	1,45	0,17
Rosmarina Bianc	0	11,0	12,5	5,60	2,57	0,70
	1	12,0	13,5	5,66	2,37	0,68
	2	11,2	13,9	6,27	2,26	0,35
	5	11,5	14,8	6,72	2,53	0,33
Local outgoing ancient varieties						
Jir Gadzhi	0	12,0	15,5	7,52	1,16	0,33
	1	11,5	13,9	8,16	1,13	0,32
	2	13,0	14,8	9,05	0,85	0,17
	5	12,0	15,5	8,94	0,60	0,17
Sary Tursh	0	10,5	13,7	7.06	0,85	0,66
	1	11,0	12,9	7,76	0,77	0,63
	2	11,0	13,3	8,27	0,61	0,50

Apple variety	Stages (months)	TSS	DM	Reducing sugar	Sucrose	Acidity (as malic acid)
	5	10,5	13,9	6,90	0.83	0,50
P - value		≤ 0,05	≤ 0,05	≤ 0,05	≤ 0,05	≤ 0,05

Table 4 shows that the titratable acidity of the apples also 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 of their initial titratable acidity.

The decrease in titratable acidity during apple storage results from the natural consumption of organic acids in fruit respiration and metabolism. Organic acids (primarily malic acid) serve as respiratory substrates and energy sources for apple cells. During ripening and senescence, apple enzymes actively oxidize organic compounds, converting them into water, carbon dioxide and metabolic intermediates. The longer apples are stored, the more their life processes subside and acids break down, making the flesh less sour. At temperatures higher than those in a refrigerator, metabolism proceeds faster, so acids degrade more rapidly.

At the same time, the total dry matter content (DM) in apples of four varieties increased during storage, namely by 37.19% (Reinette de Champagne), 9.02% (Reinette Simirenko), 2.41% (Candile Synap) and 18.40% (Rosmarina Bianc). The exceptions were the local aboriginal forms of Jir Gadzhi (for which this indicator remained at the initial level of 15.5%) and Sary Tursh (for which this indicator was 13.7% at the beginning of storage and remained almost unchanged at the end of storage – 13.9%).

The increase in dry matter concentration in apples stored under uncontrolled conditions is mainly associated with intensive moisture evaporation (desiccation). As fruits lose water, total apple weight decreases, mathematically increasing the relative proportion of dry matter (sugars, acids, pectins) in the remaining volume.

However, there are exceptions to this rule. Decreases or unchanged levels of dry matter in certain varieties are attributable to the following biological factors.

Apples are living organisms. During storage, they consume sugars and organic acids for respiration. If a variety's rate of sugar breakdown exceeds its rate of moisture loss, the absolute and relative amounts of dry matter decrease.

Varieties with thick skin, a strong cuticular layer or a heavy wax coating lose water very slowly. Their desiccation is minimal, so the consumption of dry matter through respiration becomes the dominant factor.

In our experiment, this hardly altered the overall upward trend in reducing and total sugars across all varieties. Thus, reducing and total sugar content increased, respectively, by 35,56 and 37,81% in *Reinette*

de Champagne apples; 9,18 and 25,85% in *Reinette Simirenko*; 35,38 and 41,96% in *Kandil Sinap*; 20,0 and 13,78% in *Rosmarina Bianc*; and 9,56 and 21,43% in *Jir Gadzhi*. Only in *Sary Tursh* apples did reducing and total sugar content decrease by the end of storage, by 2,27% and 2,28% compared with their initial levels.

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

Fruits accumulate starch during ripening. During subsequent storage, this complex carbohydrate breaks down into glucose, fructose and sucrose. As starch decreases and the proportion of free sugars increases, apples become sweeter and softer.

Thus, during this storage period, certain substances decreased relative to their initial content: vitamin C by 53,51% (*Rosmarina Bianc*) to 94,82% (Sary Tursh), and titratable acids by 24,24% (*Sary Tursh*) to 83,96% (*Reinette Simirenko*).

Over the entire storage period, reducing and total sugar content increased relative to their initial levels: by 35,56 and 37,81% in *Reinette de Champagne* apples; 9,18 and 25,85% in *Reinette Simirenko*; 35,38 and 41,96% in *Kandil Sinap;* 20,0 and 13,78% in *Rosmarina Bianc*; and 9,56 and 21,43% in *Jir Gadzhi*, respectively. The exception was *Sary Tursh*, in which reducing and total sugar content decreased relative to their initial levels by 2,27 and 2,28%, respectively.

Over the same period, total dry matter content in apples increased relative to its initial level by a minimum of 2.41% (*Kandil Sinap*) and a maximum of 37,19% (*Reinette de Champagne*), meaning that these apples became drier and less juicy. The exceptions were the local indigenous forms *Jir Gadzhi* (in which the value remained at 15,5% of apple fresh weight) and *Sary Tursh* (in which the value was 13,7% initially and 13,9% of apple fresh weight at the end of storage).

Five months of storage under conditions of controlled natural ventilation showed high fruit shelf life, while the dynamics of changes in ascorbic acid content and acidity depended on varietal characteristics.

4.2.3. Yield and chemical composition of direct-pressed fruit juices of traditional apple varieties.

Apples and apple juices are among the main export products of the agricultural sector of the Guba Khachmaz region, where the favorable climate allows harvesting rich harvests of both local and international varieties adapted to the conditions of the region [21]. The technological potential of local raw materials lies in its economic efficiency and biochemical properties [22].

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

Local producers have the technical, technological, and often analytical capabilities to produce high-quality fresh, stored, and processed apple products that meet all the requirements of national and international regulations. Juice authenticity control (identification) requires a comprehensive analytical approach. Standard tests are not enough to rule out falsification and confirm the claimed name of the juice. An in-depth analysis of the indicators is needed in combination with adjustments to natural factors - climatic conditions of harvest, geography of cultivation and processing features - which objectively change the natural composition of the product [23, 24, 25, 26].

The main international documents on the assessment of the quality and safety of fruit juices and nectars are the CODEX STAN 247–2005 standard (with subsequent updates until 2025) and the AIJN Code of Practice of the European Fruit Juice Producers Association [27, 28]. They regulate the product composition, terminology, and control methods.

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

The AIJN Code of Practice was developed by the European Fruit Juice Association (AIJN); it describes in detail the criteria for authenticity and physico-chemical parameters of juices and is therefore used by manufacturers and laboratories to detect adulteration. It makes a clear distinction between the concepts of “100% juice”, “reconstituted juice”, “nectar” and “fruit drink". It contains requirements for the ripeness, purity and safety of the original fruits, as well as for identification - checking the conformity of the natural composition of the juice of a particular fruit - and strict restrictions on the addition of sugar, acids and flavors to natural juices. It includes: 29 reference manuals on specific types of fruits and vegetables (each ranging from several pages to full regulations); guidelines on proper hygiene; microbiological indicators, instructions for cleaning tanks, standards for pesticides and other specific recommendations. Since AIJN regularly reviews and supplements standards individually (for example, by making targeted amendments to recommendations for the production of apple, lemon or pear juices), the total volume of the entire package of documents is hundreds of pages.

Physico-chemical and biochemical analyses, as components of the general procedure for juice identification, are carried out with mandatory consideration of information on the varietal characteristics and chemical composition of raw materials and finished products, as well as geographical, climatic, agricultural and technological factors [29, 30].

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

Therefore, the identification of quality indicators of varietal apple juices and the limits of their natural deviations is an important task.

Apples and apple juices are among the main export products of the agricultural sector of the Guba Khachmaz region, where the favorable climate allows harvesting rich harvests of both local and international varieties adapted to the conditions of the region [21]. The technological potential of local raw materials lies in its economic efficiency and biochemical properties [22].

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

Local producers have the technical, technological, and often analytical capabilities to produce high-quality fresh, stored, and processed apple products that meet all the requirements of national and international regulations. Juice authenticity control (identification) requires a comprehensive analytical approach. Standard tests are not enough to rule out falsification and confirm the claimed name of the juice. An in-depth analysis of the indicators is needed in combination with adjustments to natural factors - climatic conditions of harvest, geography of cultivation and processing features - which objectively change the natural composition of the product [23, 24, 25, 26].

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Physico-chemical and biochemical analyses, as components of the general procedure for juice identification, are carried out with mandatory consideration of information on the varietal characteristics

and chemical composition of raw materials and finished products, as well as geographical, climatic, agricultural and technological factors [29, 30].

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

Therefore, the identification of quality indicators of varietal apple juices and the limits of their natural deviations is an important task.

The data in Table 5 on the chemical composition of direct-pressed juices from August and October apples of the above varieties show that the TSS content in juices increased sharply from 09.08 to 25.10.

Calculations show that during this period, the TSS content in juices from *Reinette de Champagne*, *Jir Gadzji* and *Gara Tursh* apples increased by *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% to 10.5 ± 0.2%, that is, by 0.7%.

As a result, as of 25.10, the TSS content in juices, depending on the apple variety, ranged from 10.5 ± 0.2% (*Sary Tursh*) -14.0 ± 0.4% (*Jir Gadzhi*).

The higher concentration of TSS in direct-pressed juices compared to the standard requirements for natural apple juice (10° on the Brix scale) gives local processors several key advantages: less water needs to be evaporated to produce concentrated juice (70 °Brix), which reduces gas or electricity costs; the yield of concentrated juice from such raw materials is higher., than from apples with a minimum content of soluble solids.

Table 5

Changes in the content of some key nutrients and vitamin C in direct-pressed juices from apples of early introduced and local autochthonous varieties, depending on the degree of maturity (% of crude weight).

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

The component composition of August and October direct-pressed juices from separately examined *Azerbaijan* apples was as follows (%): 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. The TSS content increased from the beginning of August to the end of October from 11.2 to 12.0 g/100 g, i.e. by 0.8%.

Table 6, which presents data on the yield of direct-pressed juice from unripe and ripe apples, as well as on its taste and color, shows that the yield of juice and its organoleptic properties strongly depend not only on the time of apple harvest (and, consequently, on the degree of maturity), but also on the variety.

Some varieties (*Naila*, *Gara Tursh*, *Sary Tursh*, *Jir Gadzhi*, *Reinette Simirenko*) the juice yield from the unripe fruits of the first decade of August was significantly lower than from the fruits of the end of October, in others (*Reinette de Champagne, Golden Delicious* and *Starkrimson*) - higher. The yield of juice from *Shikhi Jani* apples also increased by the end of October, but only slightly.

By the end of the second decade of October, the lowest juice yield among all 9 varieties was shown by *Starkrimson* (56.8 ± 0.5%), and the highest - Reinette de Champagne (77.8 ± 0.7%), *Reinette Simirenko* (77.8 ± 0.7%), Shikhi Jani (77.8 ± 0.7%), *Golden Delicious* (75.0 ± 0.7%) and *Sary Tursh* (75.5 ± 0.7%).

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

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

- - More than 75% (*Reinette Simirenko, Reinette de Champagne*, etc.) - excellent result. In industrial production, 65–70% is considered a good juice yield. An indicator close to 80% means that the fruits are as juicy as possible, have a fine cellular structure and easily release moisture when pressed.
- - Below 60% (*Starkrimson*) is a low indicator. It is economically unprofitable to process such apples into juice - almost half of the weight will be spent on dry squeezes.

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

October 1-the end of October is the time when varieties such as Reinette Simirenko, *Reinette de Champagne* are just reaching optimal technological maturity, the starch in the fruits has already turned

into sugar and the cell walls have softened, but have not yet collapsed, the apple tissues are maximally saturated with juice, which is easily separated during pressing. At the same time, earlier or more specific varieties (for example, *Starkrimson)* by mid-October, in the conditions of Azerbaijan, they may simply ripen directly on the tree or during storage. When overripe, the flesh of apples becomes “cotton-like”, powdery, and the juice is strongly bound by pectins and practically does not stand out when pressed.

1. 2. *Renettes* and *Golden Delicious* have dense, fine-grained and crispy flesh. When these apples are crushed, an ideal structure (puree) is formed, which allows the juice to pass very well through filters and presses. The outsider variety, *Starkrimson*, is genetically predisposed to rapid loosening of the pulp. When overripe *Starkrimson* is crushed, a thick puree is formed, during which the juice also remains in the squeezes.
2. 3. The juice yield directly depends on the amount of soluble pectins: if there is too much soluble pectin (which happens when fruits are overripe), the juice becomes viscous, turns into jelly and lingers inside the cells.

The leading autumn-winter varieties in mid-October maintain a balance in which the hydrolysis of pectin provides juiciness, but does not turn the pulp into mush. As for the local Azerbaijani varieties (such as *Shikhi Jany* and *Sary Tursh*), this indicates their ideal adaptation to the climate - by October they accumulate an optimal balance of acids, sugars and moisture.

From the same Table 6, it can be seen that after 4 hours of exposure to the open air, direct-pressed juices from ripe apples of the varieties *Sary Tursh*, *Reinette de Champagne*, *Shikhi Jani* and *Naila* either still remained light or only slightly darkened, indicating their relative resistance to undesirable enzymatic transformations.

The yield of juice from slightly sour *Azerbaijan* apples was 70.0% in early August and 55.4% at the end of October; the August juice remained light after 4 hours of exposure, while the October juice slightly darkened.

Table 6
Changes in the yield and organoleptic 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).

CONCLUSIONS

In modern conditions, when the global market dictates its own harsh rules, transnational commercial varieties of pears and apples have practically replaced the local classics. By narrowing the range to a dozen global varieties, humanity is endangering food security.

Today, a counter trend is growing in the world - the demand for authenticity and local products. There is a renewed interest in old varieties from producers of traditional cider and organic juices. Amateur gardeners are increasingly looking for seedlings "from childhood" in nurseries, keeping them on their plots. Scientists and enthusiasts are creating pomological gardens to preserve the gene pool for future generations of breeders.

The traditional apple varieties of early introduction to the Guba Khachmaz zone and the varieties of folk breeding grown here historically represent a unique gene pool with high adaptability to local climatic conditions, resistance to pathogens, unique taste qualities and a unique biochemical profile.

The results obtained confirm the value of traditional varieties for breeding and producing authentic local products.

They can be used to: register the genetic and biochemical characteristics of rare varieties for future generations; identify marker genes responsible for high acidity, hardness of pulp or resistance to diseases; analyze how old varieties survived for decades without modern chemicals and pesticides; enrich fundamental science with information about the variability of the metabolism of cultivated plants; create unique local products (authentic wines, vinegars, juices) associated with a particular region.

Declarations

Competing interests

The authors declare that they have no conflict of interest.

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Figures

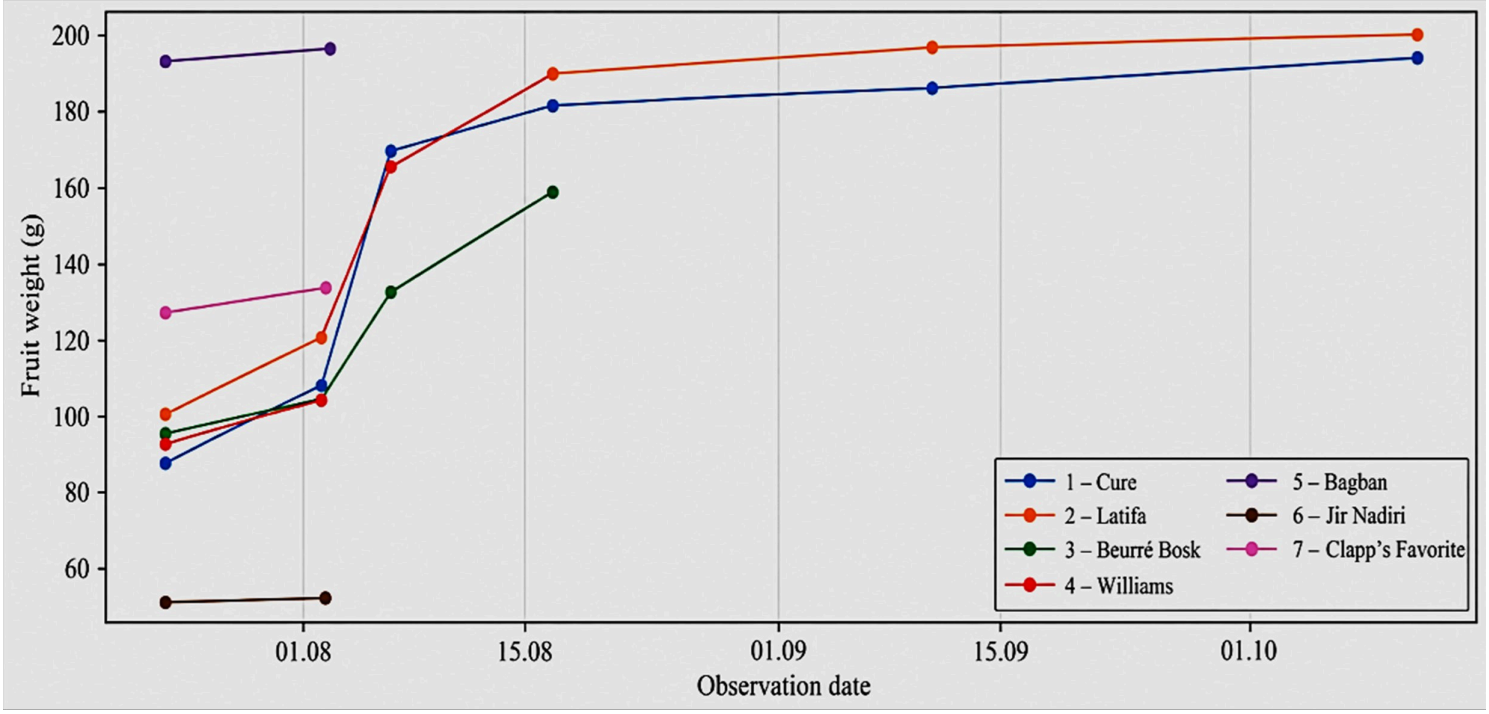


Figure 1

Change in the weight of pear fruits, starting from the end of the first decade of July and ending with the harvest period.

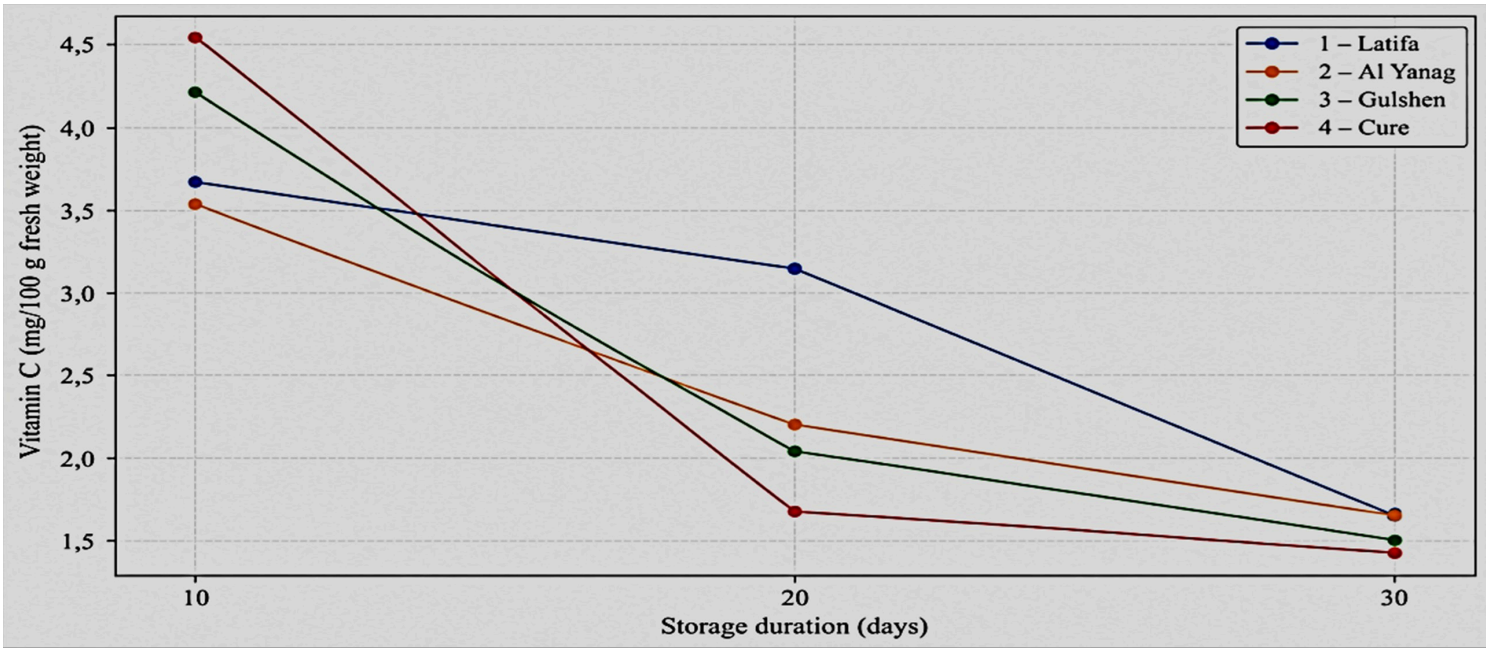


Figure 2

Changes in the vitamin C content in late-ripening pears during their post-harvest storage for one month under natural ventilation at a temperature of +10...+12 °C

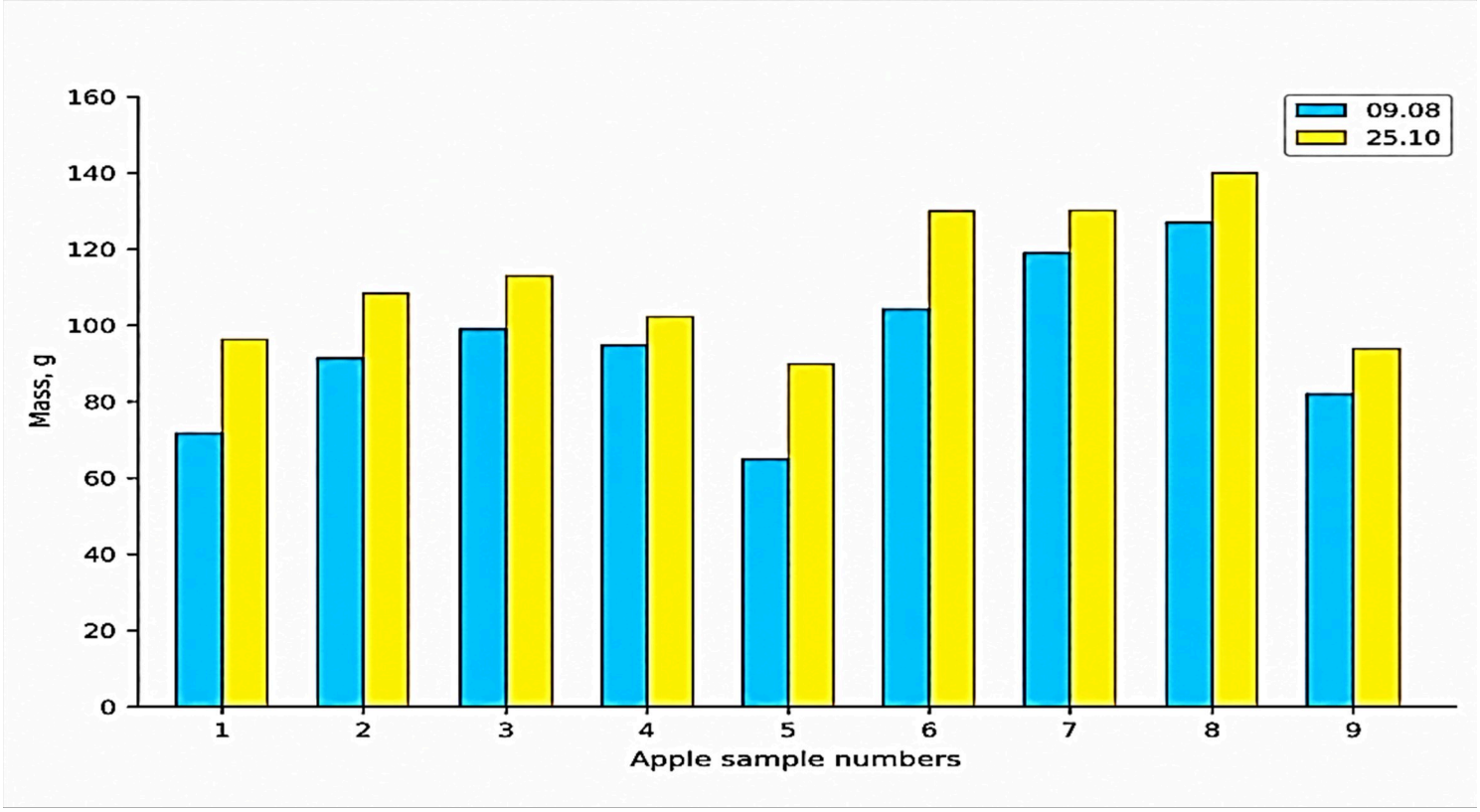


Figure 3

The weight of one individual fruit at the end of the first decade of August and the middle of the last decade of October for different varieties of apples: 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*.

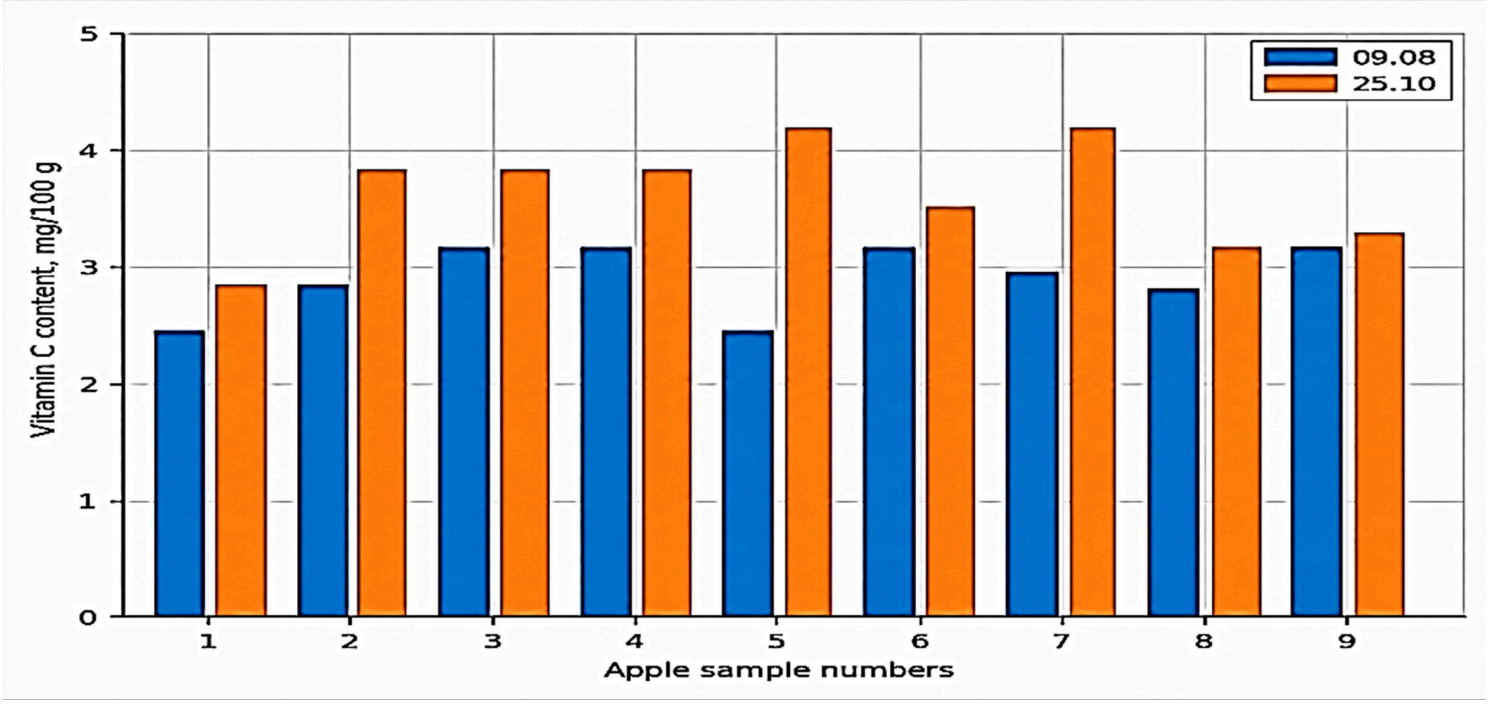


Figure 4

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- *Shikhi Janı*; 9-*Sary Tursh*.

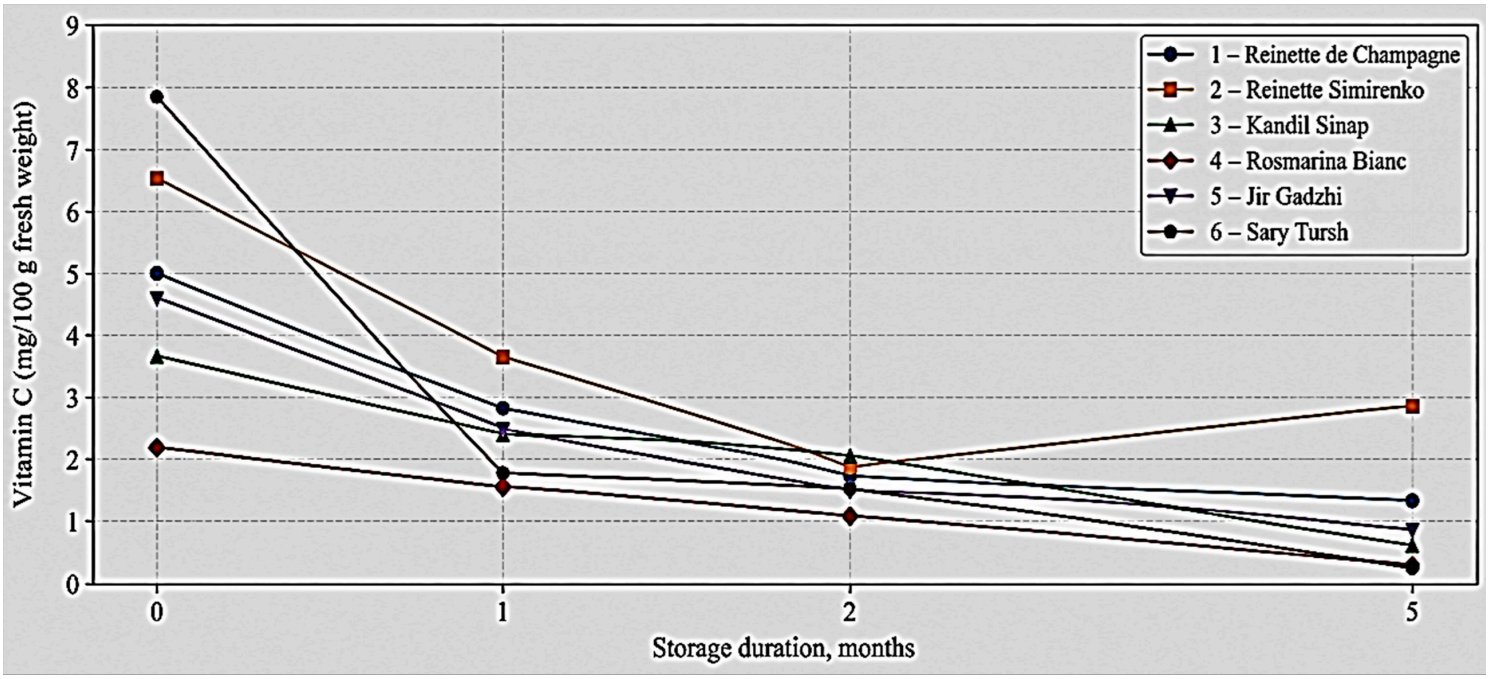


Figure 5

Changes in the vitamin C content in apples of late varieties during their post-harvest storage for five months under natural ventilation conditions with a gradual decrease in temperature from +10...+12 °C in October-November to +2...+4 °C in winter.

Supplementary Files

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- floatimage1.png