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CHANGES IN THE CHEMICAL COMPOSITION OF APPLE JUICE DURING RIPENING AND STORAGE

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Abstract

The chemical composition of apples is not constant and is shaped by a range of interrelated factors. These include varietal characteristics, climatic and weather conditions, temperature regimes, availability of water and mineral nutrients, as well as post-harvest storage conditions, among others. Variations in these parameters significantly influence the qualitative and quantitative profile of apple juice constituents throughout the processes of fruit ripening and storage.

However, the biochemical and morphological characteristics of fruits undergo changes across different stages of development, while in certain cultivars and varieties this variability remains relatively limited. One of the key indicators is the optimal harvest time of the fruit, which is determined by the efficiency and direction of biochemical processes driven by the accumulation of dry matter. The dry matter content of fruits is predominantly composed of carbohydrates, including sugars, starch, cellulose, and pectin substances. The objective of the study was to investigate changes occurring in fruits during the ripening stage and throughout the storage period. The research focused on winter apple cultivars, namely Semerenko and Golden. Analysis of fruits harvested at different stages of maturity showed that the concentration of phenolic compounds decreases as ripening progresses. In the Semerenko cultivar, when apples are stored under refrigerated conditions, the rate of organic acid degradation remains relatively uniform over the entire storage period. In overripe fruits, the breakdown of organic acids begins at an earlier stage. The titratable acidity decreases in direct proportion to the reduction in malic acid content. Across different stages of apple fruit maturity, acidity and phenolic compound levels decline, whereas sugar concentrations increase. When pectin substances become solubilized, apple fruits develop a granular texture, which adversely affects juice yield and extraction efficiency. During storage, fruit senescence leads to a reduction in the molecular weight of proteins.

Keywords

apple fruit, chemical composition, ripening period, storage, quality changes, developmental stages, acidity, juice.

Introduction

The chemical composition of apples is inherently dynamic rather than static. It is influenced by a combination of factors, including cultivar and variety, climatic and weather conditions, soil fertility and fertilization practices, fruit size variability, and storage conditions.

However, alongside changes in biochemical and morphological traits across developmental stages, certain cultivars and varieties exhibit relatively low variability. One of the principal biochemical indicators is the harvest timing of the fruit, which reflects the efficiency and direction of biochemical processes associated with the accumulation of dry matter (3,4). In specific apple cultivars, characteristics such as pronounced aroma, distinct acidity, juiciness, or other sensory attributes are genetically determined. Compounds within apples are unevenly distributed among different anatomical parts, including the peel, flesh, and seeds. Sugars are primarily concentrated in the flesh, whereas the peel is rich in waxy substances composed mainly of pentosans and dietary fibers. The seeds contain higher levels of proteins and oils (2). Aromatic compounds accumulate predominantly in the peel, while the seeds are characterized by the presence of the glycoside amygdalin.

Approximately 97% of the total mass of an apple consists of the flesh, while the peel accounts for about 2.5%, and the seeds represent roughly 0.1–0.4%. In naturally smaller fruits, the relative proportion of peel and seeds is higher than in larger apples.

All constituents of apples can be broadly classified into water-soluble and water-insoluble components (1).

One of the key quality indicators of fruit is its suitability as raw material at harvest, which is determined by the amount of accumulated dry matter reflecting the efficiency and direction of biochemical processes. The major fraction of dry matter in fruits is composed of carbohydrates, including sugars, starch, cellulose, and pectic substances (10).

Water-soluble substances represent the primary nutritional components of fruits. In apples, their content ranges from 7.5% to 23% or higher. Variations in the concentration of water-soluble solids directly affect juice density, which typically ranges from 1.030 to 1.100. Apple water-soluble constituents include sugars, organic acids, tannins, pigments, nitrogen-containing compounds, pectins, mineral elements, and other minor components (5–7).

As indicated above, the objective of the study was to observe changes in the chemical composition of apples at different stages of development and during storage.

Materials and Methods

The research was conducted in the experimental fields of Tashkent State Agrarian University.

Winter apple cultivars, namely Semerenko and Golden, were selected as the objects of the study. Fruit quality parameters and chemical composition were determined using standard analytical methods.

The phenological stages of ripening were determined at the following dates: ripening period — 20 September, 30 September, 7 October, 25 October, and 5 November; harvest dates — 22 October, 30 October, 7 November, and 15 November.

Results and Discussion

Special attention should be given to the content of water-soluble substances in apples, as this parameter determines both the quality and yield of apple juice. The total juice output is directly related to the concentration of dissolved solids (8). Accordingly, when the amount of soluble solids in apple juice is measured using a refractometer and the water content of the fruit is also determined, the juice content of the apple raw material can be calculated using the following formula:

$$X = a + ab/\mathbf{100}$$

x- juice content

a- water content in apples (%)

b- dry matter content in apple juice (%)

The equation $x = ab / 100$ represents the amount of dissolved dry substances contained in 100 kg of apples.

Indicators measured at different ripening stages of apple fruits showed that the concentration of phenolic compounds decreases as ripening progresses. These findings confirm the compositional changes occurring in apples during ripening and subsequent storage (Table 1).

Changes in the Chemical Composition of Apple Juice During Ripening and Storage

Table-1

Date of alysis	Reducin ugars, %	Sucrose,	Total gars, %	Acidity, %	Phenolic mpounds, l	Density, cm³
Sept.20	4,43	-	4,43	1,20	-	1,0312

Sept.30	5,05	-	5,09	1,25	-	1,0335
Oct.07	5,18	-	5,28	1,20	0,30	1,0410
Oct.15	5,80	0,30	6,60	1,13	0,20	1,0420
Oct.25	6,70	0,80	7,60	1,05	0,20	1,0435
Nov.05	6,90	0,80	7,70	1,09	0,15	-
Fruit harvesting time						
Oct.22	6,85	1,30	8,15	0,99	0,13	1,0447
Oct.30	7,08	1,44	8,40	0,98	0,09	1,0459
Nov.7	7,10	2,23	9,30	0,80	0,08	1,0467
Nov.15	6,9	3,80	10,90	0,75	0,09	1,0469

The results presented in the table indicate that the analyses correspond to the stages of fruit ripening and harvest. The contents of sucrose, reducing sugars, and total sugars increase progressively during the ripening period. The maximum total sugar content is observed at harvest time, reaching 10.90%, whereas at the onset of ripening it is 4.43%, representing an increase of 6.47%. As sugar levels rise, a corresponding decrease in acidity is observed. Fruit density increases throughout ripening, reaching its maximum value at harvest, when it attains 1.0469.

Overall, among the dissolved solids, sugars represent the predominant fraction of dry matter. Apple fruits contain mainly three types of sugars—glucose, fructose, and sucrose—with fructose being present in the highest proportion. According to some authors, sucrose occupies a leading position within the total sugar content, while others report contrasting interpretations (6,10).

When organoleptic characteristics are taken into account in studies of the chemical composition of apples, it is often found that sucrose constitutes approximately one-third of the total sugar content influencing fruit taste. However, in industrial processing, the overall sugar level of apple juice is sufficient, and the principal sugars of apples are readily fermentable by yeast (9).

One of the principal components of apple juice responsible for its tart and refreshing taste is organic acids. The dynamics of organic acid accumulation in different apple cultivars indicate that, across all varieties—particularly summer and autumn types—acidity declines during fruit growth and ripening. It was determined that the concentration of organic acids decreases by more than twofold approximately one month prior to harvest, and this downward trend is also observed throughout the entire fruit development period (10).

A widely held view among some authors is that titratable acidity is equivalent to the concentration of free acids. However, this assumption is not entirely accurate, since during the titration of polybasic acids the equilibrium shifts toward the formation of acidic ions.

In biochemical processes—such as apple fruit ripening—changes in titratable acidity are accompanied by alterations in pH. During metabolic reactions, organic acids may be consumed and can bind with specific cations, thereby influencing the overall acid–base balance of the fruit (8,10).

During the processes of fruit ripening and maturation on the tree, as well as throughout storage, changes occur in the aromatic compounds and peel pigments of apples, accompanied by a reduction in moisture content and a decrease in acidity, dextrins, and polysaccharides.

Studies on the dynamics of organic acid transformations have shown that, during low-temperature storage of the Golden cultivar, the rate of acid degradation and fruit mass remains unchanged regardless of the harvest date. In fully ripe apples, degradation processes were observed to develop earlier over time. The decline in titratable acidity was found to be directly related to the reduction in malic acid content (5,7).

During the ripening period of apple fruits, the conversion of starch into sugars represents one of the key physiological indicators. In addition, portions of pectic substances and hemicelluloses are also transformed into sugars. As a result, an increase in sugar content within apples is observed as ripening progresses and continues during short-term storage.

Throughout ripening and storage, apple fruits gradually soften. This softening is primarily caused by the transformation of insoluble pectins in the cell wall into soluble pectins. Changes in cell wall density and pectin solubilization consistently lead to the softening of apple tissues.

Conclusion

Based on the conducted research, the following conclusions can be drawn: during the ripening of apple fruits at different developmental stages, acidity and the concentration of phenolic compounds decrease, while sugar content increases. The solubilization of pectin within apple tissues leads to a mealy and granular texture, which negatively affects juice separation. During storage, fruit senescence results in a reduction in the molecular weight of proteins.

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