RESEARCH ON THE DYNAMICS OF QUALITY INDICES OF WINTER APPLE VARIETIES DURING THE STORAGE PERIOD

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RESEARCH ARTICLE

Abstract
Winter apple varieties are well-suited to long-term storage in warehouses. Apple harvesting must be carried out at the optimal time, determined by a series of quality indicators. The values of these indicators change during the storage period and are closely correlated with storage conditions. The study of the behavior of different apple varieties during storage has made it possible to develop specific technologies to reduce losses in terms of both quantity and quality of fruit.

Keywords: apple, quality indices, storage, storage conditions.
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INTRODUCTION

Winter apple varieties rank first in our country both in terms of total production and the amount of fruit stored nearly from one harvest to the next. The long shelf life of apple varieties is due to their chemical composition, structural properties, and intensity of physiological processes. Winter varieties have the ability to continue ripening after being picked from the trees, which allows them to be harvested before reaching eating maturity. Shelf life depends on several factors: species, variety, harvest time, orchard type, fruit size, fruit health, agricultural techniques used, and storage conditions.

Among seed fruits, apples have the best shelf life, both in terms of duration and quality, which remains good compared to other seeded fruits. Fall varieties have a high ripening capacity and can be kept for 2-3 months after harvest, while winter varieties have the longest shelf life. This storage and ripening capacity depends primarily on the fruit's chemical composition and the provision of optimal storage conditions. The ripening process is accompanied by changes in fruit quality, evidenced by sensory (organoleptic) indicators (color, taste, aroma, firmness) and chemical quality indicators (total carbohydrate content, ascorbic acid content, titratable acidity, and carbohydrate/acidity ratio).

These quality changes during storage are due to physiological processes within the fruit. Biochemical reactions in the fruit are catalyzed by enzymes, which determine the direction and intensity of these processes. Enzyme activity plays a role in establishing the quality attributes of mature fruit and, subsequently, in the decline of these attributes as overripening occurs. In apples, the activity of pectic enzymes (polygalacturonase, pectin methyl esterase) increases during the ripening period. In unripe apples, there is a rise in the activity of invertase, which catalyzes the breakdown of sucrose into glucose and fructose, as well as an increase in enzymes involved in glycolytic and pentose phosphate pathways: glucophosphate isomerase, phosphofructokinase, aldolase, and pyruvate decarboxylase. Ascorbate oxidase activity also rises during apple storage, correlating with ascorbic acid degradation.

Apple firmness is determined by the content of pectic substances, cellulose, hemicellulose, pentosans, hexosans, cell turgidity and elasticity, and the size of intercellular spaces. Studies on apples have shown an increase in firmness due to the deposition of cellulose microfibrils in cell walls. The firmness value increases from 12 g/cm² on June 9 to 23 g/cm² on October 17 for Golden Delicious and from 13 g/cm² to 16 g/cm² for Jonathan (Stoll, K., 1961, cited by Burzo, I., 1986). An increase in the volume of intercellular spaces also contributes to a decrease in fruit firmness, which correlates with the specific fruit weight. During apple ripening, specific gravity decreases from 1.0100 to 0.7100 due to cell growth, which causes an increase in intercellular space volume.

Apple color is characteristic of the species and variety and is due to pigments in the epidermal cells. The main pigments in apples are anthocyanins (cyanidin-3-arabinoside, cyanidin-3-galactoside, cyanidin-3-rutinoside) and flavonoids (quercetin-3-galactoside, quercetin-3-glucoside, quercetin-3-xyloside, quercetin-3-rutinoside). Anthocyanins are found in epidermal cells and sometimes in 2-3 layers of hypodermal cells, changing color with pH. At a pH of 3, the color is red. Flavonoid pigments, which are yellow, complement the anthocyanins in giving the fruit its color. Autumn-winter apples harvested before ripening undergo significant color changes during ripening.

Flavor is a characteristic of each species and variety, encompassing the complex sensations caused by the presence of multiple substances and their relative proportions. To determine changes in flavor characteristics, it's necessary to track alterations in the content of carbohydrates, organic acids, phenolic compounds, and other chemicals involved in flavor during storage and ripening.

At harvest, carbohydrates are primarily found as starch. In fall varieties, starch occupies about half of the fruit cross-section, whereas in winter varieties, starch is present in a 0.5 cm area around the seed cavity, indicating a large reserve for prolonged storage. During ripening, starch undergoes enzymatic hydrolysis by α and β-amylases, resulting in increased glucose content.

The organic acid content in apples decreases during ripening, as acids are used as respiratory substrates or converted to other organic compounds. Malic acid, the primary acid in apples, oxidizes readily, giving ripened fruit a mildly acidic and sweet taste.

The ratio of total carbohydrates to titratable acidity increases during storage due to shifts in carbohydrate and acid metabolism.

Apple aroma is produced by volatile compounds such as hydrocarbons, organic acids, esters, and terpenes. Apples harvested at optimal times lack fully developed aroma, which evolves as the fruit ripens and involves over 156 chemical compounds.

Ascorbic acid content varies with fruit ripeness. For instance, in the Jonathan variety, ascorbic acid was found to be 10.2 mg/100 g during the setting stage but fell to 7.9 mg/100 g at eating maturity (Gherghi, A. et al., 1981, 1983, 1984, 1989). Generally, ascorbic acid content decreases due to oxidation, converting it into 2,3-dioxo-L-gulonic acid (Burzo, I., 1986; Beceanu, D., 1994, 1998, 2000; Beceanu, D. et al., 2000, 2003; Potec, I. et al., 1983, 1985; Radu, I. F., 1967; Ardelean, A.G., 2009, 2015, 2019).

MATERIAL AND METHODS

The research was conducted in 2023 at the Faculty of Environmental Protection Oradea.

Golden Delicious, Red Delicious, Starkimson and Pinova apple varieties, which are winter varieties, were used in the trials. Harvesting took place in early October.

Research was carried out on both fresh fruit and fruit stored for three months.

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Research was conducted on both freshly harvested fruit and fruit stored for three months. Before storage, the fruits were sorted, and unsuitable ones were removed (damaged by insects or disease, wounded, bruised, etc.). Storage occurred under natural conditions in a private cellar, with apples placed in a single layer on wooden shelves.

Sampling took place on the day of harvest. Fruit samples were collected from several trees at both the edge and the middle of each row. From each selected tree, fruit was taken from different canopy levels with varying light exposures.

Total titratable acidity was determined by neutralization with a 0.1 N sodium hydroxide alkaline solution, using a 1% alcoholic phenolphthalein solution as a color indicator. Soluble dry matter was measured refractometrically directly in the field using a Zeiss portable refractometer, allowing the optimal harvest time to be assessed based on this value. Vitamin C content was determined by the iodometric method.

RESULTS AND DISCUSSIONS

The chemical analyses carried out on winter apple varieties after harvest and after temporary storage revealed the mean values of the quality indices presented in Tables 1 and 2.

Table 1

Main quality indices of apples at harvest

Variety / average of samples	Soluble dry matter (%)	Titratable acidity (malic acid g/%)	Vit. C (mg/100g)
Golden Delicious	13.81	0.31	15.2
Red Delicious	12.61	0.29	14.1
Starkimson	13.91	0.22	13.5
Pinova	12.01	0.24	12.9

Table 2

Main quality indices of apples after storage

Variety / average of samples	Soluble dry matter (%)	Titratable acidity (malic acid g/%)	Vit. C (mg/100g)
Golden Delicious	12.11	0.19	11.9
Red Delicious	11.9	0.11	11.0
Starkimson	12.02	0.17	10.1
Pinova	11.23	0.10	9.4

Analysis of the data shows that golden delicious apples have a relatively low malic acid content of 0.31 g at harvest, which decreases to 0.19 g of malic acid after three months of storage. This relatively low malic acid content at harvest is characteristic of the variety, as golden delicious belongs to a group of varieties with naturally lower acidity. Low rainfall during the growing season, particularly toward the end (september-october), also contributed to these findings.

After three months in cellar storage, malic acid content decreased by about 30-40%, depending on the variety. This reduction can be attributed to the heightened metabolic activity of the stored fruit under cellar conditions, where climatic factors (temperature, relative humidity, and gas content) could not be controlled.

The soluble dry matter content also declined due to enzymatic hydrolysis of starch by α- and β-amylases during ripening. Similarly, ascorbic acid content generally decreased across all apple varieties, primarily due to oxidation and conversion into 2,3-dioxo-l-gulonic acid.

Creating a favorable storage climate was achieved solely by ventilating the cellar. Notably, under these storage conditions, the apples could be kept for a maximum of four months. Beyond this period, the fruit began showing signs of tissue turgidity loss and was affected by storage diseases, necessitating sorting and preparation for consumption.

At the same time, the organoleptic qualities of the fruit changed, impacting the carbohydrate/acidity ratio. This ratio of total carbohydrates to titratable acidity increased during storage due to metabolic changes in carbohydrates and acids. Consequently, the fruit became sweeter while retaining the flavor characteristic of each variety. Structural and textural firmness declined as the fruit gradually lost turgidity.

CONCLUSIONS

The following conclusions can be drawn from the study:

The lower acidity at harvest is a varietal characteristic, with Golden Delicious being a less acidic variety.

This relatively low acidity is also influenced by the climatic conditions of the production year, marked by low rainfall during summer and autumn as well as high temperatures.

The decrease in malic acid content after three months of storage can be attributed to the storage conditions. Since the storage area was not air-conditioned, ventilation was the only option for managing environmental factors.

Soluble dry matter content decreases during ripening due to starch hydrolysis.

Vitamin C content decreases in all varieties as a result of oxidation.

Under these storage conditions, there is a marked increase in the respiratory activity of the fruit, leading to more intense metabolism of organic acids.

Changes in the fruit's chemical composition have altered its sensory (organoleptic) properties, resulting in a sweeter and more aromatic profile in ripe fruit.

Color intensity is characteristic of fully ripe varieties and fruits.

Structural firmness is reduced due to the loss of fruit turgidity.

Under the described storage conditions, it became necessary to end storage after four months, as the fruit exhibited changes in tissue turgidity and taste properties and was affected by various storage diseases (heart rot, apical rot) and phytopathies (powdery mildew and suberification).

Further research is recommended to examine qualitative changes in apples during storage.

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