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HORTICULTURAL STUDIES

RESEARCH PAPER

Identification of Quality Characteristics of Autochthonous Karasüt Apple during Cold Storage

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Abstract

The main objective of the research was to assess weight loss, respiration rate, firmness, soluble solids content (SSC), titratable acidity and vitamin C content of the autochthonous Karasüt apple throughout cold storage. The 'Granny Smith' cultivar was used as positive control. The fruit was kept at a temperature of 0.0±0.5°C and relative humidity of 90±5%. Quality losses were observed in the apples during cold storage. The weight loss of Karasüt apple (6.70%) was higher than that of Granny Smith (2.20%) at the end of cold storage. A lower respiration rate was measured in the Karasüt apple (1.23 nmol CO_2 kg^{-1} s^{-1}), compared to the positive control (1.53 nmol CO_2 kg^{-1} s^{-1}) at harvest. On the contrary, the respiration rate was higher on days 30 and 60. The fruit firmness of Granny Smith (27.14 N) was higher than that of Karasüt (22.47 N) at the end of cold storage. During the cold storage, a higher SSC was obtained from Karasüt apple compared to the positive control. However, titratable acidity was lower in Karasüt apple. In the first two measurements of cold storage, the vitamin C of Karasüt apple was higher than that of the positive control. As a result, it was revealed that Karasüt apple had faster quality losses during cold storage than Granny Smith apple cultivar.

1. Introduction

Apple, a pome fruit, can be grown in a very wide range of climates worldwide, including temperate, tropical, and subtropical regions. It is the fourth most widely produced fruit globally, following citrus, grapes, and bananas (Palmer et al., 2003). Among temperate climate fruit species, it located the first place in terms of production. Türkiye produces approximately 4.5 million tons (about 5%) of the 93.14 million tons of apples produced worldwide, ranking second after China in terms of production volume (FAO, 2023).

Apple is consumed not only fresh but also in various processed forms, such as fruit juice, puree, concentrate, as filling for pastries, in sauces, wines, and as dried fruit. Due to its richness in vitamins, minerals, and especially phenolic compounds like flavonoids, along with their antioxidant properties, apples are highly favored by consumers (Boyer and Liu, 2004). The widespread cultivation of apples and their long storage period allow consumers easy access to this fruit (Palmer et al., 2003). Naturally, the extensive cultivation and production of apples across different regions lead to the utilization of numerous standard and autochthonous cultivars to match consumers' preferences. Autochthonous varieties specific to certain regions are consumed more than commercial varieties in their respective areas. Moreover, these autochthonous varieties often receive a "Geographical Indication" certification, enabling them to be sold at higher prices, thus providing higher profits to the producers. Additionally, this recognition contributes significantly to promoting the region and serves as a source of pride and motivation for the autochthonous producers (Şahin, 2013).

The main aim of this research was to determine the weight loss and changes in certain quality characteristics of the locally grown 'Karasüt' apple during cold storage in the Bulancak district of Giresun province, Türkiye. With the first data obtained from this study, it is aimed to obtain a geographical indication designation for the autochthonous 'Karasüt' apple.

2. Material and Methods

In the study, autochthonous Karasüt apple variety and Granny Smith cultivar (*Malus domestica* Borkh.) were used as plant materials (Figure 1). Fruit were manually harvested at the commercial ripening stage from a producer orchard in Bulancak district of Giresun province, Türkiye. Harvesting for Karasüt and Granny Smith apples took place approximately 160 and 170 days after full bloom, respectively. The Granny Smith apple trees, aged 10 years, were grafted onto MM111 rootstocks, while the 20-year-old Karasüt apple trees were grafted onto seedling rootstocks.

The fruit were placed into 5 kg plastic crates and transported to the laboratory using refrigerated vehicles at [15±0.5°C and 85±5% relative humidity (RH)]. Damaged and diseased fruit were removed and discarded. The remaining fruit were distributed in the plastic crates, with approximately 20 fruit per crate to represent each replication. A total of 12 crates were prepared for each variety. Subsequently, the fruit were subjected to precooling with cold air at +4±0.5°C and 90±5% RH for 24 hours. Following precooling, the fruit were stored at 0.0±0.5°C and 90±5% RH for a period of 120 days, during which measurements and analyses were conducted at monthly intervals (30, 60, 90, and 120 days). Three crates were taken for each measurement period, and each crate represented one replication (3 rep).

2.1. Weight loss, respiration rate and fruit flesh firmness

For each replication of Karasüt and Granny Smith apples, fruit in the crates were weighed on a digital scale with a precision of 0.01 g (Radwag, Poland) before storage. Subsequently, the same crates were weighed again during each measurement period (measurements were conducted inside the cold storage). Based on the initial and post-storage measurements, the weight loss was calculated as a percentage (%) (Ozturk et al., 2017).

For respiration rate measurements, 3 fruits were taken from each replication. They were placed in a gas-tight 2-liter container, and after 1 h, the CO_2 concentration in the environment was measured using a digital carbon dioxide gas analyzer (Vernier, Oregon, USA) with a typical accuracy of 5.0%). The measured values were then determined based on the volume and weight of the fruit inside the container and presented as nmol CO_2 kg^{-1} s^{-1} (Ozturk et al., 2022).

Measurements for fruit firmness, 10 fruits were used in each replication. Measurements were made at 3 different points (at an angle of 120 degrees between them at the equator) on the equatorial part. Fruits' peel was excised using a cutter, and subsequently, measurements were taken using the 11.1 mm tip of an Effegi penetrometer (FT-327, McCormick, USA). The obtained results were presented in N (Newton) (Ozturk et al., 2017).

2.2. Titratable acidity, vitamin C, soluble solids content

Initially, five fruit from each replication were washed with tap water, followed by rinsing with distilled water. A slice of approximately 3-4 cm width

Figure 1. Image of studied apple varieties.

was cut from each fruit using a stainless steel knife, and the peels were removed. The slices were then pureed in a blender (Philips, Türkiye), and the obtained homogenate was filtred through a cloth to obtain fruit juice. Soluble solids content (SSC) measurement in the fruit juice was carried out using a digital refractometer (PAL-1, USA), and the values were presented as a percentage (%). For titratable acidity, a sufficient amount of fruit juice was taken and diluted with distilled water. The pH of the solution was titrated with 0.1 N sodium hydroxide until it reached 8.2. The acidity was determined based on the amount of sodium hydroxide consumed, and the values were presented as % malic acid (Ozturk et al., 2017). For vitamin C measurement, approximately 10 mL of fruit juice was taken, and the method described by Karakaya et al. (2020) was employed using a digital reflectometer (Merck RQflex plus 10, Germany). The obtained values were presented as mg 100 g^{-1}.

2.3. Statistical analysis

In the study, data were subjected to normal distribution testing using the Kolmogorov-Smirnov Test. Homogeneity of variance was assessed using the Levene test. Descriptive statistics for the data meeting the assumptions were calculated, and analysis of variance (ANOVA) was performed for evaluation. Following the analysis of variance, the significance level among varieties was determined using the Tukey multiple comparison test (α=5%). The data obtained from the study were analyzed using IBM SPSS version 20.0 statistical analysis program.

3. Results and discussion

In the study, it was observed that throughout all measurement periods, the weight loss of Karasüt apples during cold storage was higher than that of Granny Smith apples. Conversely, Karasüt apples exhibited lower firmness compared to Granny Smith apples during all measurement periods. At the end of the storage period, the weight loss in Karasüt apples (6.69%) was approximately 3 times higher than that in Granny Smith apples (2.20%). On the 30^{th} and 60^{th}-day, a significant difference ($p<0.05$) in respiration rate was detected between Karasüt and Granny Smith apples. While Karasüt apples exhibited lower respiration rates than Granny Smith apples at harvest, significantly lower respiration rates were obtained during the first two measurements of the storage period (Figure 2).

After harvest, weight loss in fresh fruits and vegetables is an expected occurrence. However, the extent of this loss directly affects storage duration and fruit quality. Therefore, minimizing weight and firmness loss is desired. Of course, during the weight loss period, texture deterioration and softening of the fruit occur. In our study, the measured weight and firmness loss varied among varieties. In Karasüt apples, both weight and firmness loss were higher during cold storage. Indeed, researchers (Ghafir, 2009; Reig et al., 2017) have reported that weight and firmness loss may vary depending on the cultivar. Additionally, in apple varieties, the respiration rate in Karasüt apples was higher than that in Granny Smith apples during the first two measurements of storage. This higher respiration rate in Karasüt apples may have resulted in the greater weight and firmness loss. Simultaneously, the hydrolysis of cell wall polysaccharides occurs as starch breaks down, leading to rapid softening of the fruit (Jan and Rab, 2012; Ren et al., 2020). Moreover, variations in pectin content among different varieties can contribute to differences in firmness levels (Billy et al., 2008).

During harvest and cold storage, it was observed that the SSC values of Karasüt apples were significantly higher than those of Granny Smith apples. In contrast, the titratable acidity values were found to be lower. Karasüt apples exhibited a 42% higher SSC than Granny Smith apples at harvest. However, at the end of storage, Karasüt apples had a 33% higher SSC compared to Granny Smith apples. At harvest, the acidity of Granny Smith apples (1.79%) was 3 times higher than that of Karasüt apples (0.57%). However, at the end of storage, the measured acidity value in Granny Smith apples was 4.67 times that of Karasüt apples. Regarding vitamin C, significant differences ($p<0.05$) were observed between apples during both harvest and the 30^{th} and 60^{th} days of storage. Both at harvest and during the first two measurement periods of storage, Karasüt apples had significantly higher vitamin C content than Granny Smith apples. Throughout the storage period, a higher vitamin C loss was observed in Karasüt apples (Figure 3).

With ripening, starch in the apple is broken down and converted into sugars. SSC, which provides information about taste during consumption, increases with the progress of ripening, while acidity decreases. The breakdown of starch into sugars is among the fundamental reasons for the increase in SSC in fruit (Burdon et al., 2016). In the study, higher SSC and lower acidity were measured in Karasüt apples compared to Granny Smith apples during cold storage. Furthermore, variations in vitamin C content were observed between the varieties during harvest and the first two measurements of storage. Additionally, a decrease in vitamin C content was observed in both varieties during storage. Indeed, Hayat et al. (2005) reported that there may be potential decreases in vitamin C content during storage. Additionally, Nour et al. (2010) reported differences in vitamin C content among apple cultivars. In parallel with our findings, Jan and Rab (2012) stated that the apple cultivars (Royal Gala, Mondial Gala, Golden Delicious and Red Delicious) they examined were different in

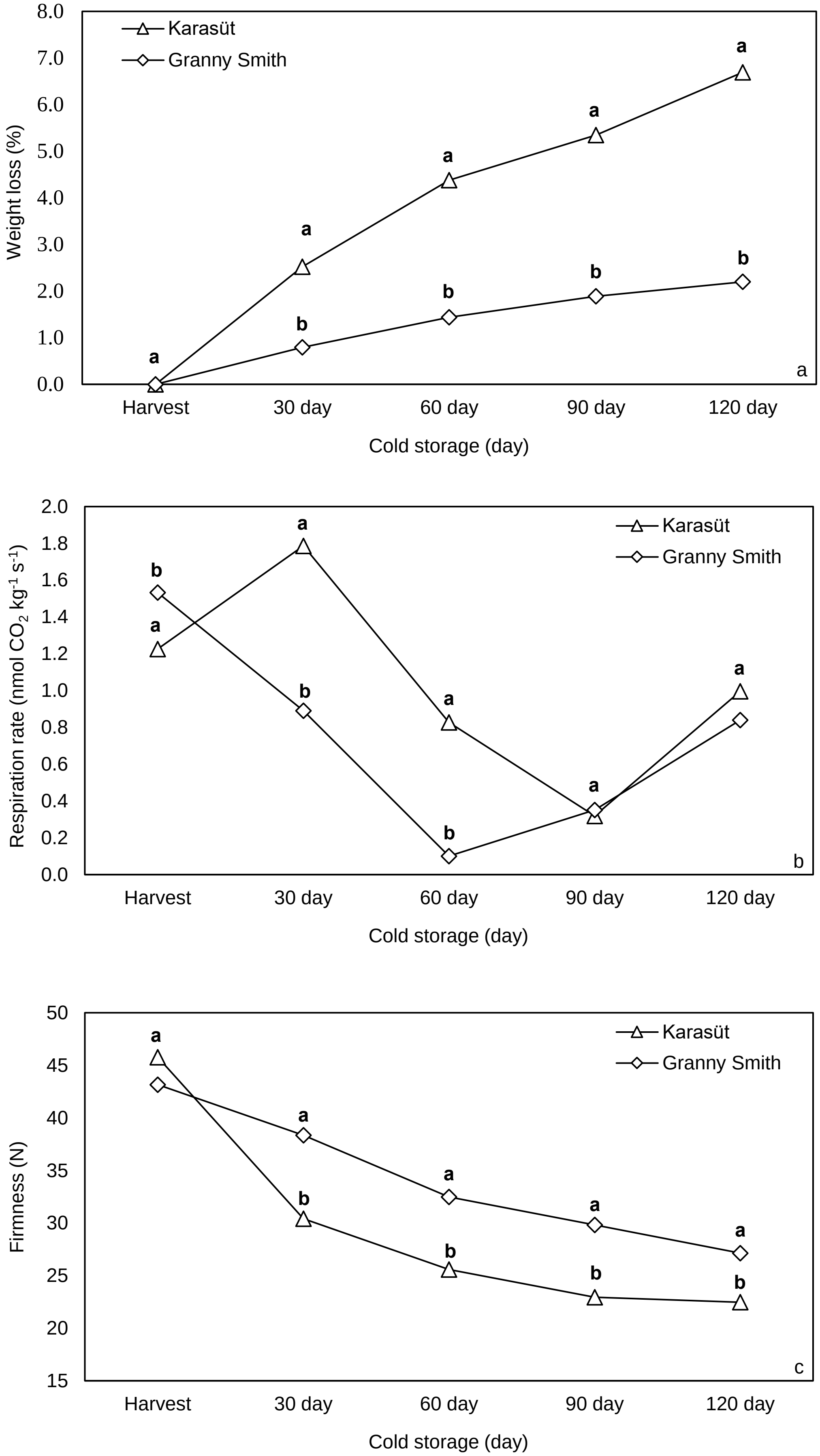

Figure 2. Weight loss (a), respiration rate (b) and firmness (c) of autochthonous Karasüt variety and Granny Smith cultivar apples during cold storage (Means indicated with same lower-case letter vertically didn't significant, Tukey's test, p<0.05).

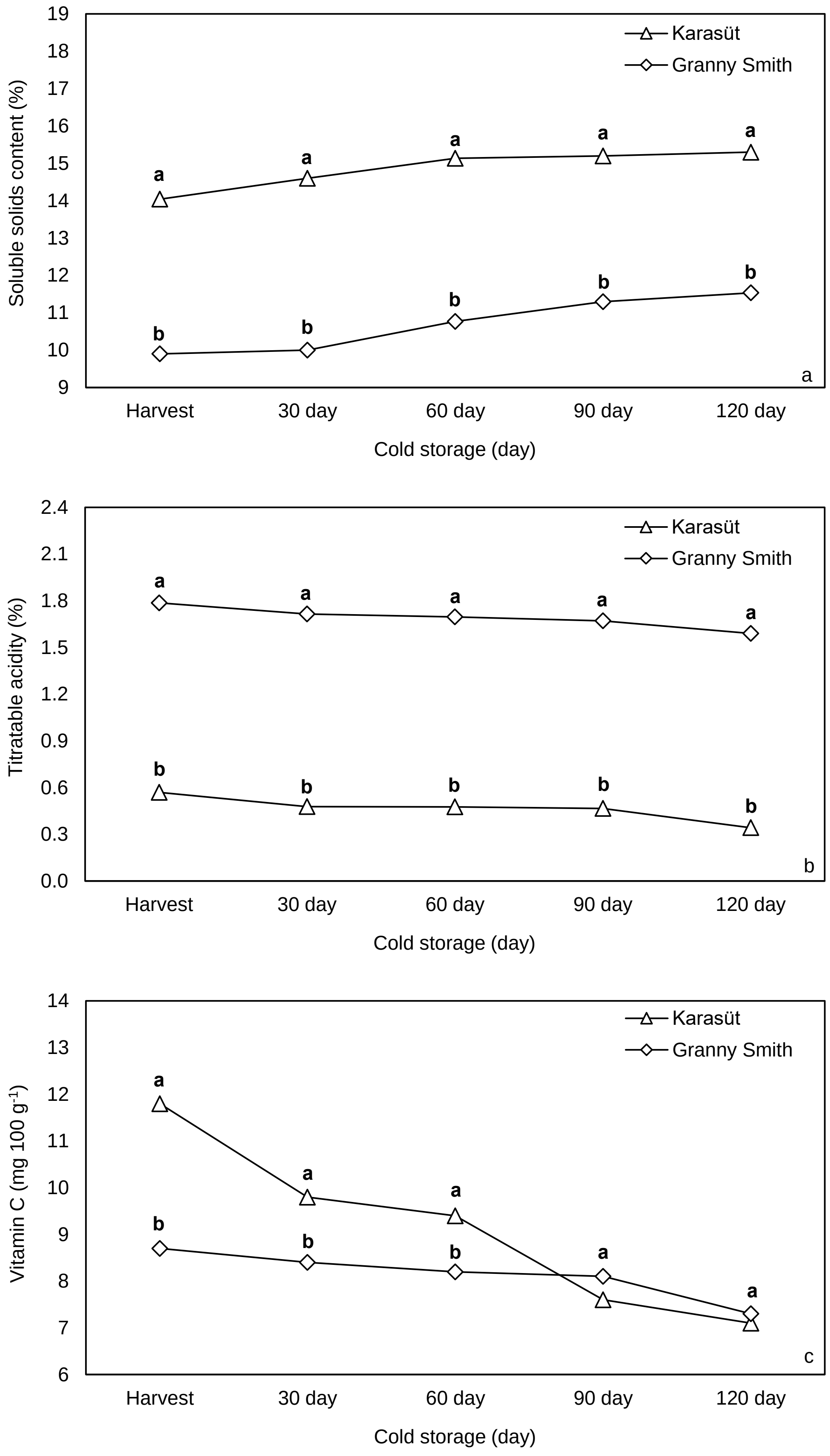

Figure 3. Soluble solids content (a), titratable acidity (b) and vitamin C (c) of autochthonous Karasüt variety and Granny Smith cultivar apples during cold storage (Means indicated with same lower-case letter vertically didn't significant, Tukey's test, p<0.05).

vitamin C, SSC and acidity contents at harvest and during storage. Furthermore, some researchers have indicated that certain factors such as higher storage temperature, injuries, low relative humidity, and chilling damage during storage may lead to a decrease in vitamin C content (Nour et al., 2010; Mditshwa et al., 2017).

4. Conclusion

As a result, during storage, all fruit experience quality losses. However, the extent of these quality losses is significant consumer acceptance. This study revealed that Karasüt apple had higher weight and firmness losses compared to Granny Smith apple. At the end of cold storage, the weight loss of the Karasüt apple was approximately 3 times greater than that of the Granny Smith cultivars. The flesh firmness of the Karasüt apple was 17% lower than that of the Granny Smith apple. Additionally, the vitamin C loss in Karasüt apple was more pronounced during cold storage.

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