COLD STORAGE EFFECTS ON ETHYLENE EMISSION, CO_2 ACCUMULATION, AND TSS VARIATION IN GOLDEN DELICIOUS APPLES AT 3°C

AZ ETILÉN TERMELŐDÉS, A CO_2-FELHASZNÁLÁSRA ÉS A TSS VÁLTOZÁSÁRA A GOLDEN DELICIOUS ALM 3°C-ON TÖRTÉNŐ TÁROLÁSA ESETÉN

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Abstract

The study investigates the ethylene production and respiratory metabolism of Golden Delicious apples stored at 3°C for 13 weeks. Apples were all picked at a maturity stage corresponding to the commercial harvest date and stored at 3°C with a relative humidity of 85±5 %. The results showed that TSS increased at the beginning of the storage while the ethylene release increased slowly under the 3ºC cold storage. The results of this study show that after 7 weeks of storage, the ethylene release rate peaked at 35.5 $\mu L \cdot kg^{-1} \cdot h^{-1}$, followed by 14.9 $\mu L \cdot kg^{-1} \cdot h^{-1}$ after 11 weeks. Then it progressively reduced and remained at a low level. Fruit respiration rate decreased during cold storage at 3ºC and gradually rose after storage. The goal is to develop strategies to extend the shelf life of apples while reducing post-harvest food waste. By reducing food waste, we reduce the ecological footprint of apple cultivation.
Keywords: *cold storage, Golden Delicious apple, Ethylene, CO_2, TSS (Total Soluble Solids)*
JEL kód: *O13, Q10*

Összefoglalás

A tanulmány a 13 hétig 3°C-on tárolt Golden Delicious almák etiléntermelését és légzési anyagcseréjét vizsgálja. Az almákat normál betakarítási időszakban a megfelelő érettségi állapotban szedtük le, és 3°C-on, 85±5 % relatív páratartalom mellett tároltuk. Az eredmények azt mutatták, hogy a TSS a tárolás kezdetén nőtt, míg az etilén felszabadulás lassan nőtt a 3°C-os hűtőházban. Ennek a vizsgálatnak az eredményei azt mutatják, hogy 7 hét tárolás után az etilén felszabadulási sebessége 35,5 $\mu L \cdot kg^{-1} \cdot h^{-1}$-nél érte el a csúcsot, majd 11 hét után 14,9 $\mu L \cdot kg^{-1} \cdot h^{-1}$ érték. Aztán fokozatosan csökkent, és alacsony szinten maradt. A gyümölcs légzési sebessége a 3°C-os hideg tárolás során csökkent, majd a tárolás után fokozatosan emelkedett. A cél olyan stratégiák kidolgozása az alma eltarthatóságának meghosszabbítására, miközben csökkentik a betakarítás utáni élelmiszer-pazarlást. Az élelmiszerpazarlás csökkentésével csökkentjük az almatermesztés ökológiai lábnyomát.
Kulcsszavak: *hűtve tárolás, Golden Delicious alma, Etilén, CO_2, TSS (Total Soluble Solids)*

Introduction

The agricultural sector is crucial in supplying the world's population with food. However, it also significantly impacts the environment, contributing to food waste, carbon emissions, and resource depletion. As a result, sustainable agriculture and efficient postharvest management necessitate green, innovative solutions to reduce environmental impacts that preserve food quality and shelf life. The "Golden Delicious" apple is a well-known cultivar celebrated for its crisp texture and sweet flavor. This apple type's ripening and overall quality are greatly influenced by its postharvest physiology, particularly ethylene production and respiration.
The 'Golden Delicious' apple's ripening and general quality are heavily influenced by its postharvest physiology, notably ethylene production and respiration. The fruit maturation stage at harvest, storage conditions, and postharvest treatments all impact ethylene generation and respiration rates in 'Golden Delicious' apples. Apples collected at different maturation stages have varied ethylene production and respiration rates, which impact aroma compound generation and taste development. Apples stored at lower temperatures or under controlled atmospheres tend to have reduced ethylene production and respiration rates, which can delay ripening and extend shelf life (ATUNGULU et al., 2004; SAFTNER et al., 1999).
Ethylene activity is the primary factor controlling how rapidly climacteric fruit loses quality and marketability.

However, due to ethylene exposure, non-climacteric fruits and vegetables may experience degradation, loss of quality, and physiological abnormalities.

Ethylene affects skin color, cell turgor, and structural changes that result in texture loss, all of which greatly enhance the rates of decline in postharvest quality. Additionally, it accelerates respiration and activates enzymes, which start the breakdown of cell walls. However, several variables, including preharvest circumstances, fruit species, cultivar, ethylene concentration, exposure time, temperature, and relative humidity of storage, influence how ethylene affects postharvest physiology and storage (YANG et al., 2016)

The primary external element affecting respiration is temperature. Biological responses frequently increase two or three times for every 10 °C rise within the temperature range often encountered in the distribution and marketing chain (BARSA et al., 2012)

Higher temperatures may cause enzymatic denaturation, which would reduce respiration rates. According to HO et al. (2018), physiological damage brought on by extremely low temperatures may increase respiration rate.

This study investigates the behavior of ethylene, CO_2, and TSS in Golden Delicious apples stored at 3°Cover 13 weeks. There is a need to develop strategies that extend the shelf life of apples while reducing postharvest food waste. This study emphasizes the possibility of improving storage conditions to preserve food quality and meet the increasing need for ecologically responsible sustainable food systems by concentrating on postharvest physiology and its relationship to environmental sustainability.

Materials and methods

Golden Delicious Apples arrived directly after the harvest from a Hungarian farm. The fruits were stored at 3ºC under a relative humidity of 85±5 % for 13 weeks. The effect of cold storage on the TSS, ethylene production, and CO_2 rate of stored apples was studied. The measurements were repeated 3 times for each sample.

Total soluble solids (TSS) content

Apple juice was extracted using a domestic juice extractor (BRAUN, Spain, MODEL: MR-5550 BC-HC, 600 W+Turbo). The total soluble solids were determined utilizing a refractometer (Fig 1). (Ebro Electronic GmbH, Germany, Model: DR-10). The measurements were taken at equivalent intervals, from week one to week 13 and the TSS results were reported in % with an accuracy of ±0.2%.

Figure 1. Refractometer

Ethylene measurement

The production of ethylene gas was measured using a Dräeger handheld ethylene gas detector (Drägerwerk AG & Co. KGaA, Lübeck, Germany, Dräeger x-am 5000) (Fig 2). Before measurement, one Golden Delicious apple was placed in a 2L hermetically closed plastic container at 3°C. The measurements were carried out over 13 weeks, and the results were reported in μL·kg^{-1}·h^{-1}.

Figure 2. Dräeger handheld ethylene gas detector

CO_2 measurement

The production of CO_2 gas was measured using a gas detector (Ahlborn Mess- und Regelungstechnik GmbH, Holzkirchen, Germany, FYAD00CO2B10 type, digital CO_2 sensor) and data logger (Ahlborn Mess- und Regelungstechnik GmbH, Holzkirchen, Germany, ALMEMO 2890-9, 9 measuring inputs) (Fig 3). Before measurement, one Golden Delicious apple was placed in a 2L hermetically closed plastic container. The measurements were carried out over 13 weeks, and the results were reported in $mg \cdot kg^{-1} \cdot h^{-1}$.

Figure 3. Ahlborn CO_2 gas sensor

Results and discussion

During the entire duration of the test, the apple and the measuring device were placed in the same air space. Based on this, the change in the gas concentration produced in the given air space only had to be read from the display of the measuring instrument, i.e. the sampling did not affect the measurement.

Total soluble solids content

TSS (Total Soluble Solids) content initially increased over the storage period, but a decrease was seen in the end (Fig 4). In week five, the highest TSS of 14.48% was reached. BAI et al. (2004) suggest that respiration might cause TSS variations. BEGHI et al. (2014) studied the total soluble solids of apples kept at a temperature of 1–1.5°C and found a rise at the storage start, followed by variations. They found that the TSS for Golden Delicious apples ranged between 12 and 15 °Brix throughout the storage period. Although an initial increase in TSS can be observed, the later variations are evidence of the dynamic nature of fruit quality during storage, which is influenced by factors such as ripening and storage conditions.

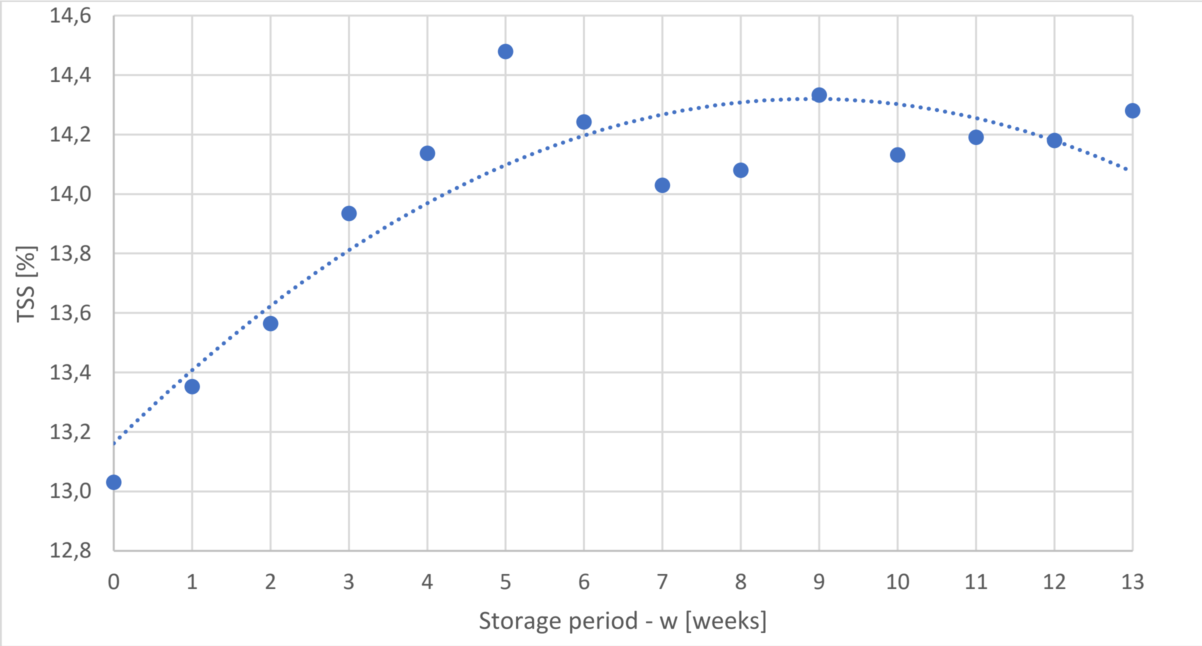

Figure 4. TSS of apple fruit during storage at 3ºC for 13 weeks

The other factor contributing to the increase in TSS is moisture loss, which raises fruit sugar content and might cause a correlation between TSS and weight loss (KASSEBI et al., 2022).

Research indicates that TSS generally increases with extended storage duration Apples lose moisture mainly through transpiration when stored. The fruit's residual soluble solids may be concentrated due to this moisture loss, increasing TSS. A higher TSS measurement results from the concentration of sugars and other soluble substances rising when water evaporates (KHAN et al., 2012).

Ethylene Release of Apple Fruit

Under the 3 ºC cold storage, the ethylene release increased slowly as shown in Figure 5. The ethylene release rate reached the first peak value of 35.5 $\mu L \cdot kg^{-1} \cdot h^{-1}$ after 7 weeks of storage and the second peak of 14.9 $\mu L \cdot kg^{-1} \cdot h^{-1}$ after 11 weeks of storage, respectively. Then, it gradually diminished and maintained a low level.

Those results agree with the work of WANG et al. (2022), who obtained similar findings for the Ethylene Release of Golden Delicious apples stored at 0ºC and 20ºC. According to their research, the ethylene release increased gradually under the 0ºC cold storage scenario, reaching its first peak after 35 days and second peak after 65 days of storage. These findings showed that ethylene production was significantly reduced by cold storage. The post-ripening impact of apple fruit is dramatically delayed because low temperatures may significantly inhibit the release of ethylene, which also explains why low temperatures delay the peak of respiration when considering ethylene's ripening action. These findings supported the hypothesis that storage temperature and duration had very distinct effects on the physiological metabolism of ethylene and respiration in apple fruit. We found that ethylene production was significantly reduced by cold storage. Like other climacteric fruits, apples experience an autocatalytic surge in ethylene synthesis during ripening. This surge accounts for the changes in texture, hardness, color, and other processes (FERNÁNDEZ-CANCELO et al., 2022).

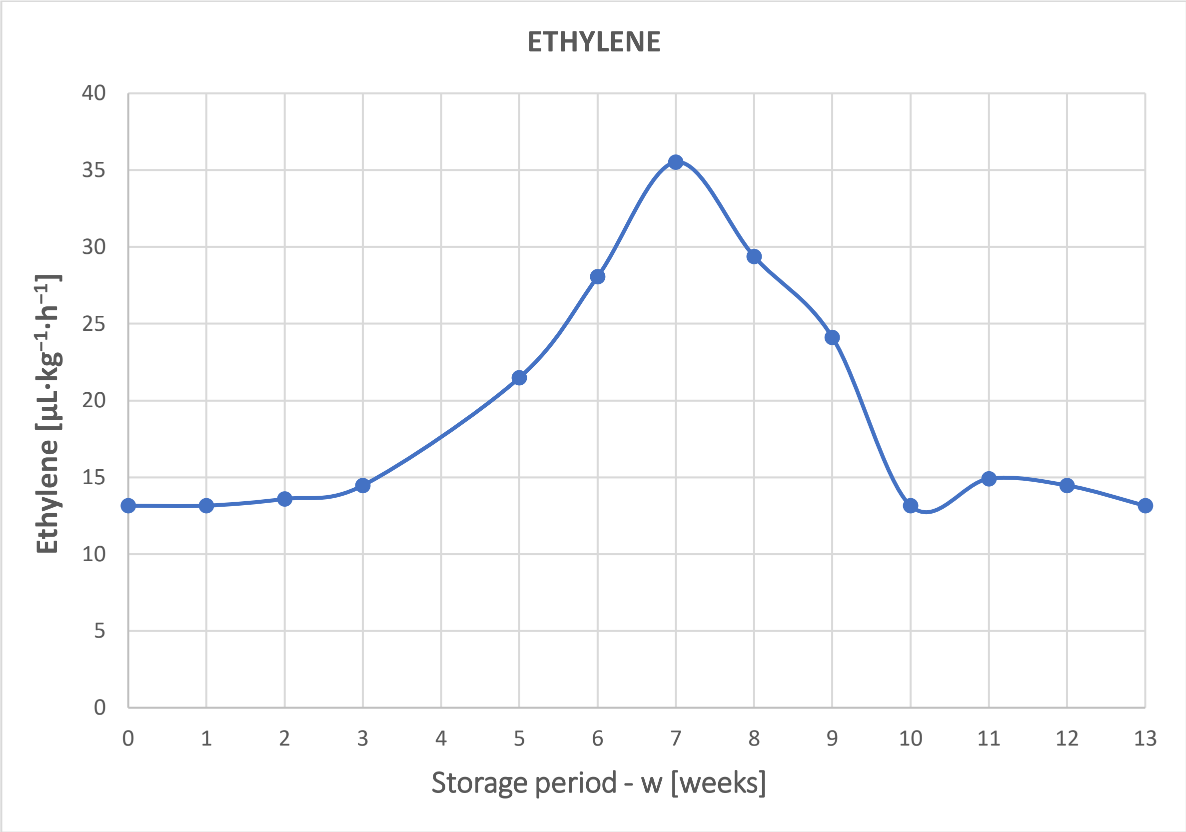

Figure 5. Ethylene release of apple fruit during storage at 3ºC

Analysis of CO_2 rate

The respiratory rate of apple fruit, a typical respiratory climacteric fruit, considerably impacts its physiological status. As shown in Figure 6, After 7 weeks, the peak respiratory rate attained its first peak value of 43.7 mg·kg^{-1}·h^{-1} and its second peak value of 24.12 mg·kg^{-1}·h^{-1} after 12 weeks of storage. The fruit respiration rate was dramatically lowered during cold storage at 3ºC and progressively increased following storage. The findings show that low-temperature storage pushed back apple respiration peak time and peak value considerably.

Those results agree with the work of WANG et al. (2022), who obtained similar findings for the Respiration Rate of Golden Delicious apples stored at 0 ºC and 20ºC.

They found that during storage, the Respiration Rate of water-cored 'Fuji' apples climbed quickly, peaking at 18.78 CO_2 mg·kg^{-1}h^{-1} after 15 days and rapidly decreasing. This largely follows the rule of the fresh-cut apple respiratory rate at various temperatures discovered by FAGUNDES et al. (2013). Cold temperatures can lower the respiratory rates of fruit. This is primarily because cold temperatures dramatically limit respiration metabolism's effectiveness by inactivating physiological and energy metabolism enzymes, such as apple respiration. During respiration, fruits utilize oxygen to break down carbohydrates and produce energy. storage at 3ºC can significantly lower the respiration rate in Golden Delicious apples. This reduction in respiration slows down the consumption of carbohydrates and the release of carbon dioxide. As a result, the fruit retains its firmness and quality for an extended period.

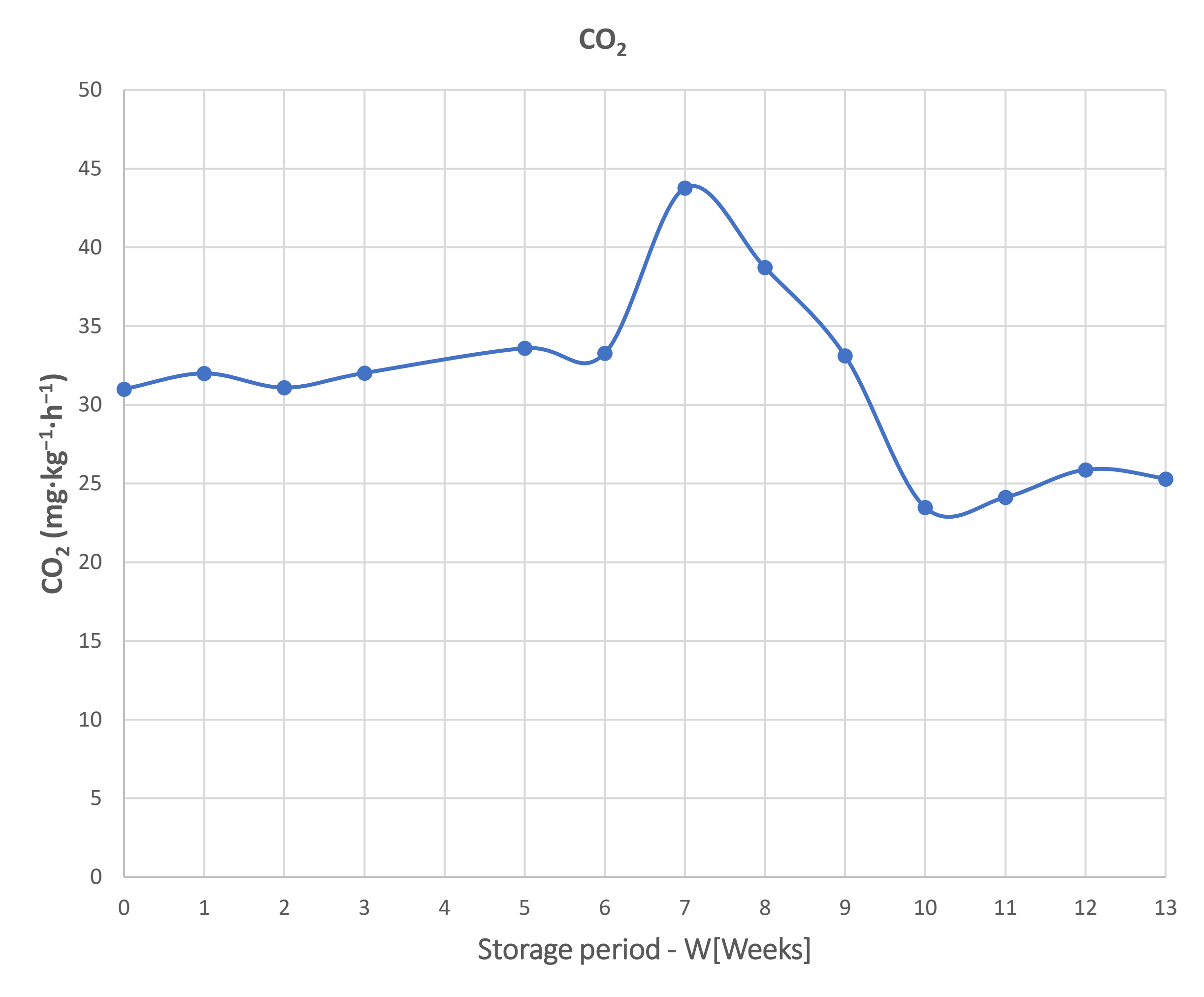

Figure 6. CO_2 release of apple fruit during storage at 3ºC

Conclusion

Cool but frost-free, well-ventilated rooms are suitable for keeping apples. It is best if the storage temperature does not rise above 5°C and does not drop below -1 °C. Based on these, we chose the 3-degree storage temperature.

Under the 3ºC cold storage, the ethylene release and the respiratory rate of apple fruit increased slowly. TSS generally increased during cold storage, indicating that flavor and quality are maintained. In apples, ethylene accelerates ripening, increasing respiration and leading to faster quality deterioration during storage. The results demonstrate that storage at 3ºC was the optimal temperature that helped slow ethylene release and respiration, extending the shelf life of apples without causing chilling injury and significantly delaying the ripening process.

Controlling storage temperature helps improve the post-harvest shelf life of these fruits and contributes to reducing food waste and promoting more sustainable agricultural practices by delaying fruit ripening and maintaining quality over a more extended storage period; frequent harvests or rapid transportation is minimized. Finally, reducing food waste affects the supply chain for apples since it uses less energy and resources for cycles of harvesting, storing, and distributing apples.

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