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THE EXAMINATION OF APPLE SHELF LIFE FROM CONSUMER STORAGE PERSPECTIVE

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ABSTRACT

Proper storage and preservation of apples is essential for consumer satisfaction and the efficiency of the food industry. The aim of this research is to investigate in detail the impact of different storage conditions on the physical and chemical properties and shelf life of apples, with particular emphasis on the differences between store and home storage.
In the experiment, commercially available Golden Delicious apples are stored in cold storage at two different temperatures (5°C and 10°C) and known relative humidity (85 RH%) to simulate consumer storage conditions. The study is conducted for 10 weeks, with weekly sampling. The parameters analysed include physical properties such as weight, size, colour and meat firmness, as well as chemical properties such as sugar and acidity. Statistical methods are used to collect and analyse the data and to search for correlations and relationships between the different parameters in order to help consumers to effectively preserve and evaluate the quality of the apples.
Home storage of apples plays an important role in economic processes, as it contributes to reducing food waste and promoting more sustainable food consumption. If consumers are able to store apples properly at home, less fruit is wasted, which reduces food waste.

Keywords: Golden Delicious apples, consumer storage, physical properties, shelf life

1. INTRODUCTION

Over the past few years, the issue of food waste has become increasingly prominent, with numerous publications and articles measuring and publicising food waste in consumer households. In Hungary, 4.53 kg/person/year of fruit and vegetables are wasted. [1] Fruits and vegetables are among the most perishable of foods. The majority of crop losses occur in the pre-harvest stage and during the handling of harvested crops. Post-harvest refrigeration, adequate humidity and proper atmospheric composition are essential to maintain freshness in storage facilities and packaging. [2][3][4]
Fruits have a very high-water content, which results in a relatively high metabolic activity compared to other plant foods such as seeds. This metabolic activity continues after harvest, making most fruits perishable. [5][6]
Storage at low temperatures slows down cellular metabolism, thus delaying the ageing of the plant and increasing the shelf-life of the fruit and vegetables. [7] Unlike perishable foods, such as meat, fruit and vegetables are living organisms and therefore continue to respire and evaporate after separation from the plant. [8][9]
During the production process, a small percentage of apples are sold after harvest, while the majority of the crop is stored for longer periods to ensure that it remains available to consumers on the market. [10] Fresh apples are usually stored commercially for 1 year. [11] Temperature is the most important parameter to maintain quality during the storage period, low temperature slows down the physiological and biochemical ripening processes in the fruit during storage by drastically reducing the metabolism of the fruit, but lower than ideal temperature leads to damage by causing unbalanced metabolism. [12] Biological reactions

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generally increase by a factor of two to three for every 10°C. [13] In order to minimise deterioration of the harvested apples, the optimum temperature is in most cases between 0-3°C. [14]
Quality is the main characteristic of food. [15] The study of the consumption quality of apples, both from a sensory and a consumer perspective, has been of interest for a long time, but only a few studies report a rigorous set of criteria. [16][17][18] Fruit quality comprises a number of factors, including surface and internal imperfections, size, colour, firmness, soluble solids and acidity, all of which are influenced by a number of factors. [19] Consumers identify the quality of apples primarily by the firmness, juiciness and sweetness of the fruit. The softness of the flesh is an indicator of low quality and the length of time the apple has been stored. [20][21][22]

2. MATERIALS AND METHODS

2.1. Subject and circumstances of measurements

The experiment investigated the effect of storage conditions on the physical and chemical properties of the fruit. The apple variety we chose was Golden Delicious, which is an excellent choice for storage studies as it is one of the most widely grown and popular apple varieties. The experimental material was obtained from a local producer, ensuring uniform quality and identical starting conditions.
The apples were placed in a controlled (RH85%) cold store, where two different temperature conditions were set: +5°C and +10°C. The choice of storage temperatures has been made considering the typical conditions that consumers might encounter in their homes, simulating conditions in a refrigerator (around +5°C) and a cold chamber (around +10°C). The duration of the experiment was 10 weeks, which provided sufficient time to monitor the impact of apple storage conditions on shelf life and quality.
During the experiment, samples were taken on a weekly basis. At the end of each week, five apples from each temperature condition were selected and tested for different parameters. The aim of the sampling was to monitor changes in weight, size, colour, flesh firmness, sugar content and acidity of the apples over time. Regular measurement of these parameters allowed us to obtain an accurate picture of how storage conditions affect the quality and shelf life of the apples.
During sampling, special care was taken to test the sunny and shady sides separately, as the influence of sunlight can significantly affect the ripening process and quality of apples. For each sample, the measured values of sunny and shady sides were recorded to get a more comprehensive and detailed picture of the effects of storage conditions.

2.2. Measurement of weight loss

The measurement of weight loss was a key parameter during the experimental period, as it directly indicates the loss of moisture content in the apple, which affects the freshness and shelf life of the fruit. Weight loss was measured using a digital scale. (Fig 1.) (Germany, Hamburg, type KPZ 2-05-4, 0-6kg ±0,2g)

***Figure 1**: Digital precision balance*

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At the beginning of the experiment, each apple was weighed, and its initial mass was recorded. Then, each week, the apples sampled during that week were re-measured again and their actual weights were recorded. The weight loss was calculated by subtracting the weight measured that week (W_{ij}) from the initial weight (W_{i0}) and expressing the result in ratios to facilitate comparison.

Weight loss was calculated using the following equations:

$$\boldsymbol{\Delta Wij} = \frac{W_{i0} - W_{ij}}{W_{i0}} \cdot \mathbf{100}, [\%], \ \boldsymbol{\Delta Wj} = \frac{\sum_{i=1}^{5} \Delta W_{ij}}{5}, [\%] \tag{1}$$

ΔW_{ij} – weight loss of the i^{th} apple at the week j compared to the zero week [%];
W_{ij} – weight of the i^{th} apple at the week j [g];
ΔW_j – the average weight loss for each week [%];

2.3. Flesh firmness change

Optimising the storage conditions of apples is key to preserving the freshness and quality of the fruit for longer. One of the most important quality indicators is the firmness of the apple flesh, which has a direct impact on the fruit's consumability and market value. Our aim was to determine which temperature is more favourable for the preservation of firmness of the apples and to suggest more efficient home and commercial storage methods based on the results obtained.
Flesh firmness was determined using Brookfield CT3 Texture Analyzer on TA-RT-KIT baseboard using TA 9 pin probe body. (Fig 2.) For evaluation of measurement parametric data (test type: TPA, target type: distance, trigger load: 6.8 g, test speed: 5 mm/s, target value: 5,0 mm [15] and results TexturePro CT V1.2 Build 9. Software was used.

***Figure 2**: Texture Analyzer CT3*

Flesh firmness (FF) change was calculated using the following equation:

$$FF_j = \frac{\sum_{i=1}^{5} FF_{ij}}{5} [\mathbf{g}], \Delta FF_j = \frac{FF_j}{FF_0}, [\%] \tag{2}$$

FF_j – the average flesh firmness change at the week j compared to data from week 0; [-]
ΔFF_j – the avarege flesh firmness at week j; [-]
FFj – flesh firmness of the ith apple at the week j; [g]

This formula allowed us to monitor the change in flesh firmness of each apple every week and to compare the effect of different storage temperatures.

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3. RESULTS AND DISCUSSION

3.1. Weight Loss

Weight loss during storage of apples is an important indicator of deterioration in fruit quality. The Figure 3. below shows the average weight loss at two different storage temperatures (+5°C and +10°C) during the 10 weeks of the experiment. (RH85%)

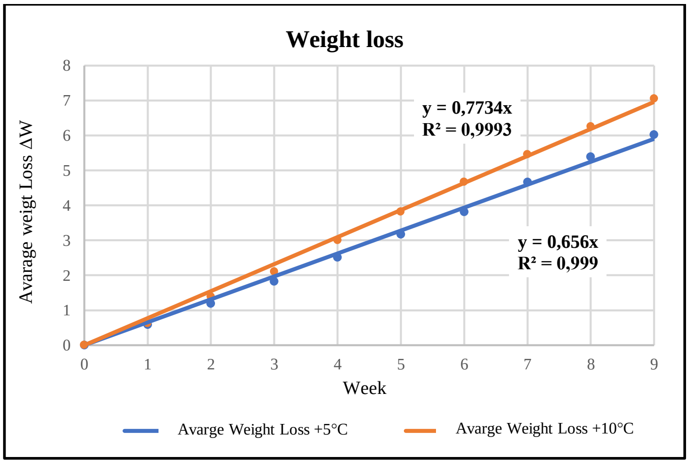

***Figure 3**: Weight loss of apple fruit during storage*

Apples stored at +5°C: the linear regression analysis shows that the average weight loss of apples per week is y = 0,656x, where the R^2 is 0.9968, indicating a strong linear relationship.
Apples stored at +10°C: the linear regression analysis shows that the average weight loss of apples per week is y = 0,7734x, where R^2 is 0.9977, which also indicates a powerful linear relationship.
More rapid weight loss is observed for apples stored at +10°C, which can be attributed to the effect of higher temperatures leading to faster moisture loss and evaporation. The R^2 values are close to 1 for both temperature groups, indicating a strong linear relationship between storage time and mass loss.
The results obtained confirm that lower temperatures (+5°C) are more effective in minimizing weight loss of apples, and it is therefore recommended to choose this temperature for longer term storage of apples. Faster weight loss at +10°C results in shorter shelf-life, which negatively affects the market value and the consumability of the fruit.

3.2. Change of flesh firmness

The results showed that under both temperature conditions, flesh firmness decreased over time. (Fig 4.) However, important differences were observed between the two temperatures. The diagram below shows the results.
Apples stored at +5°C showed a slower reduction in flesh firmness than those stored at +10°C. This suggests that lower temperatures help to preserve the firmness of the fruit for longer.
The flesh firmness of apples stored at +10°C is reduced more rapidly, which means that these fruits lose their freshness and firmness more quickly at higher temperatures.
R^2 was 0.6702, indicating a weak linear relationship between the change in meat firmness and time. This result suggests that, although there is a correlation between storage time and loss of flesh firmness, other factors may play a role in affecting the firmness of apples during storage. Therefore, further statistical tests,

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such as analysis of variance (ANOVA) and post-hoc tests are needed to more accurately evaluate and confirm the results.

The results confirm that storage at lower temperatures is better for preserving the firmness of the apples. However, based on the R^2 value, further detailed analyses and experiments are needed to fully understand the relationship between storage temperature and flesh firmness, as well as other influencing factors.

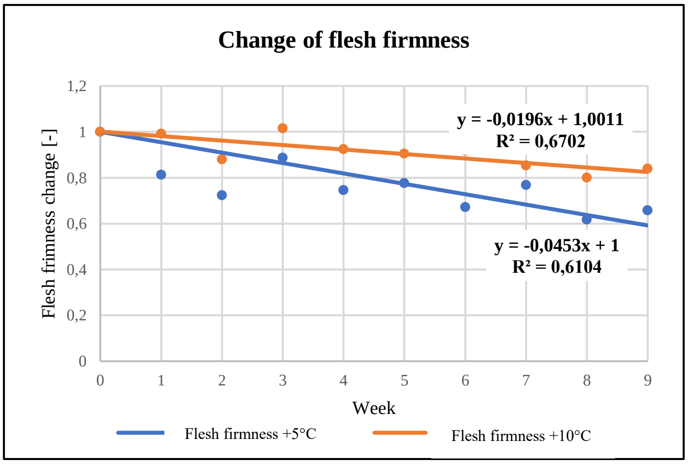

***Figure 4**: Loss of apple firmness during storage*

4. CONCLUSIONS

This research aimed to investigate the factors affecting the shelf life of apples, especially Golden Delicious apples, under different storage conditions. Through rigorous experimentation and measurement, significant results were obtained in terms of weight loss and changes in flesh firmness at +5°C and +10°C over a 10-week period. Results showed that apples stored at +5°C lost weight and flesh firmness more slowly than those stored at +10°C. Linear regression analysis showed high values of R^2 for weight loss, indicating a strong correlation between storage time and weight loss, with lower temperatures more effective in minimizing these losses. However, the R^2 value for meat firmness was 0.67, indicating a weak linear relationship, and further statistical tests are needed to confirm the results. These results may be important for improving consumer storage practices and optimizing energy consumption, contributing to the sustainability goals of the circular economy.

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