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"Agrosym 2023"

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EFFECT OF CALCIUM CHLORIDE AND DURATION OF STORAGE ON THE QUALITY OF THE APPLE CULTIVAR 'GLOSTER'

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Abstract

Apple (*Malus×domestica* Borkh.) is one of the most represented and economically most important fruit species. There are a number of calcium-containing products on the market that can be applied before or after harvest to delay fruit maturation with no negative effects on consumers. The paper also presents the results of a study on the effects of a foliar application of calcium chloride ('Stopit') on the physical and basic fruit quality properties of the apple cultivar 'Gloster'. The study was conducted for two consecutive years, and the changes in fruit weight, firmness, dimensions, soluble solids, total sugars, and organic acids content were studied during harvest and storage periods of 60 and 120 days in a regular cold chamber. Fruits treated with calcium chloride had higher fruit weight, height, width, firmness, total sugars, and ratio between total sugars and organic acids (206.0 g, 70.6 mm, 77.8 mm, 7.6 kg cm^{-2}, 10.4%, and 21.4, respectively). The storage period had a significant effect on all fruit parameters studied, except for the content of total acids. The highest values of physical properties were mesured at the moment of storage, soluble solids content after 60 days (13.2° Brix), and total sugars (10.9%) and sugar/acid ratio (22.3) after 120 days of storage. Foliar application of $CaCl_2$ during vegetation can be an effective measure to avoid losses in apple fruit quality during storage in the regular cold chamber.

Keywords: *apple*, *$CaCl_2$*, *storage*.

Introduction

Apple (*Malus* × *domestica* Borkh.) is the most important continental fruit tree species. In the global fruit production structure, apples rank fourth, behind citrus fruits, grapes, and bananas (Milošević et al., 2019). The global apple production in 2021 amounted to 93,144,358 tons, while in the Republic of Serbia, it is grown on an area of 27,034 hectares, with a total production of 513,238 tons (FAOSTAT, 2021).

Apple fruits can be consumed fresh immediately after harvest or after a certain storage period (Folta and Gardiner, 2009), and they are often stored for a longer period of time in a controlled atmosphere for production profitability reasons. During storage, intense metabolic processes occur, leading to a reduction in fruit quality (Fattahi et al., 2010). Sams et al. (2008) state that many physiological and pathological disorders of apple fruits during storage are related to low calcium (Ca^{2+}) content in fruit tissue. The concentration of calcium in plant tissue plays an extremely important role in maintaining fruit quality after harvest. Several authors (Hossain et al., 2005; Misra and Gupta, 2006; Naeem et al., 2009) emphasize that the application of calcium-based products positively affects the stabilization of cell membranes and the delay of fruit aging, maintains fruit firmness, reduces the occurrence of 'bitter pit' and internal fruit decay (Raese and Drake, 2002; Dierend and Rieken, 2007; Suljevic et al., 2011). There are numerous calcium-containing products available on the market, that are applied

before or after harvest, enabling the quality preservation of fruits without harmful effects on human health (Lester and Grusak, 1999; Shirzadeh et al., 2011).
The aim of this research was to determine the effects of foliar application of a calcium chloride-based product ('Stopit') on changes in the quality of 'Gloster' apple fruits stored under normal atmosphere.

Material and Methods

The research was conducted during the period 2018–2019 in the production-experimental apple orchard of the Fruit Research Institute in Čačak (43° 89' 40" N, 20° 43' 42" E, altitude 233 m). The orchard was established in 2006, and apple trees were grafted to the M9 rootstock. The slender spindle training system was applied. The planting spacing was 4×1.25 m (2,000 trees ha^{-1}). Standard agri agromonic and pomotechnical practices were applied during the investigation period.
'Gloster' is a German apple cultivar created at the Jork Experimental Station in 1969 by crossing the cultivars 'Glockenapfel' and 'Richared'. It ripens in mid-September, and the fruits can be stored in cold storage with normal atmosphere until the end of March. During cold storage, physiological disorders such as bitter pit, glassiness, fruit mealiness, and others may occur (Mišić, 2004).
In the experiment, a liquid foliar fertilizer with the commercial name 'Stopit' (Yara UK Ltd. Pocklington, York, UK) was applied. It is a solution of calcium chloride ($CaCl_2$) with a high concentration of calcium (12% w/w = 160 g L^{-1}). Its application is recommended in fruit trees to prevent calcium deficiency in fruits. It is used from the beginning of flowering until the end of the fruit ripening phase, especially from the fruit pigmentation phase until harvest.
The research included foliar application of the 'Stopit' ($CaCl_2$ concentration of 224 g L^{-1}). Foliar application was made to 20 trees in four replicates (a total of 80 trees per treatment) from early June to mid-August. In both years of the study, the preparation was applied four times. In 2018, the application dates were June 7, July 2 and 20, and August 15. In 2019, the application dates were June 14, July 5 and 26, and August 16. The foliar application was performed using a motorized sprayer SR 420 (STIHL International GmbH Waiblingen, Germany), at a consumption rate of 1,000 L ha^{-1}. The preparation was applied at a rate of 7.5 L ha^{-1} (150 mL in 10 L of water). The control consisted of 'Gloster' apple trees that were not treated with the 'Stopit' product. In the study the physical characteristics (weight, width, height, firmness) and basic chemical properties (soluble solids content, total sugars and organic acids content, as well as their ratio) of the fruit were investigated. These parameters were determined during the harvest period and after 60 and 120 days of fruit storage in a normal atmosphere.
Weight, height and width, fruit firmness, and soluble solids content were determined using standard morphometric methods on a sample of 80 fruits (four replicates of 20 fruits each). Fruit weight (g) was measured using a digital scale (Adventurer Pro AV812M, Switzerland), while fruit length and width (mm) were determined using a digital calliper (Carl Roth, Germany). Fruit firmness was measured using a digital penetrometer (Model FHT-803, Italy), and values were expressed in kg cm^{-2}. Soluble solids content in apple fruits was determined using a digital refractometer (Carl Zeiss, Jena, Germany) at room temperature (20 °C), and the values were expressed in °Brix. Total sugar content was determined volumetrically using the Luff-Schoorl method (Džamić, 1989), while total acidity was determined by titration, and the values of these parameters were expressed as percentages. The sweetness index, representing the ratio of total sugars to acids, was calculated.
Results are presented as mean ± standard error of the mean (SE). Differences between mean values were compared using Duncan's test in a three-way analysis of variance (ANOVA)

using the MSTAT-C statistical computer package (Michigan State University, East Lansing, MI, USA). Differences with p values ≤ 0.05 were considered statistically significant.

Results and Discussion

The results of the study on the effects of year, treatment with calcium chloride, and storage duration on the physical and chemical properties of 'Gloster' apple fruits are presented in Table 1. Analysis of variance revealed that weather conditions during the study years significantly influenced all the quality parameters of the fruits. No statistically significant differences were found in the values of soluble solids content and total acidity of apple fruits when the 'Stopit' product was applied. Significant effects of the storage time were found for all studied fruit properties, except for total acidity. The interaction effect of all factors was observed only for total sugar and acid content in 'Gloster' apple fruits, indicating that the individual effects of each factor, as well as their interactions, can be neglected. Statistically significant interaction effects conditioned by the combined action of two variability factors were recorded for the other studied pomological properties.

The results of the interaction effect of year and treatment with the 'Stopit' product on the weight, width, and height of 'Gloster' apple fruits are shown in Figure 1. The highest values for fruit weight, width, and height were observed in the treatment with the 'Stopit' product in 2018, while the lowest values were recorded in the control variant in 2019. Mišić (2004) emphasizes that the fruits of 'Gloster' apple belong to the group of large to very large fruits (180–250 g). Fruits of desirable apple cultivars should ideally have dimensions ranging from 65 to 80 mm (Gvozdenović, 1998). On the other hand, Asgharzade et al. (2012) state that foliar application of calcium chloride during the growing season influences an increase in apple fruit weight, and Amiri et al. (2008) confirmed a positive impact on fruit dimensions in their studies. Our results are consistent with the findings reported by the mentioned authors, indicating a correlation.

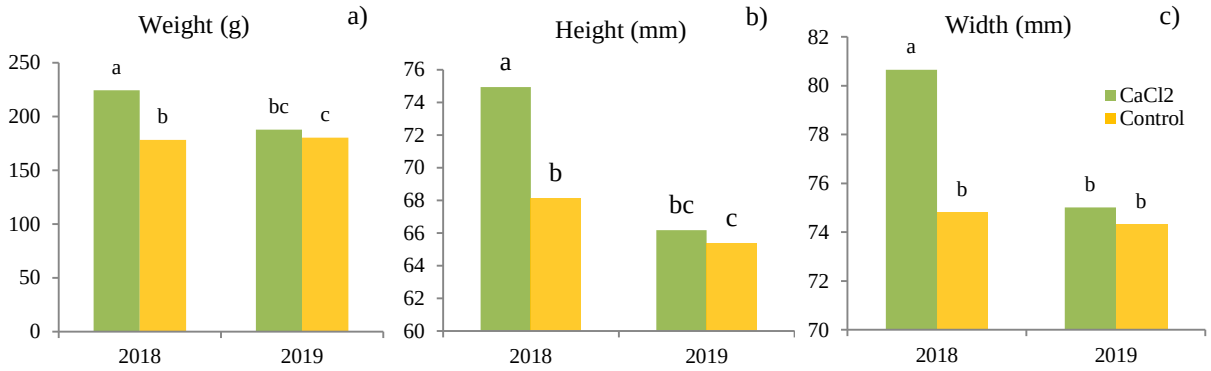

Figure 1. Interaction effect of year/treatment on weight (a), height (b) and width (c) of the fruit of apple cultivar 'Gloster'

Table 1. Influence of year, treatment of Stopit and period of storage on physical and chemical properties of apple fruit of the cultivar 'Gloster'

Treatment	Fruit weight (g)	Fruit height (mm)	Fruit width (mm)	Firmness (kg cm^{-2})	SSC (°Brix)	TS (%)	TA (%)	TS/TA
Year (A)								
2018	201.4±5.5 a	71.5±0.8 a	77.7±0.8 a	7.6±0.2 a	10.6±0.3 b	9.4±0.3 b	0.4±0.0 b	19.5±0.7 b
2019	183.9±3.5 b	65.8±0.7 b	74.7±0.6 b	6.8±0.4 b	14.1±0.1 a	11.8±0.2 a	0.5±0.0 a	22.2±0.7 a
Treatment (B)								
$CaCl_2$ (Stopit)	206.0±4.9 a	70.6±1.1 a	77.8±0.8 a	7.6±0.3 a	12.5±0.4 a	10.4±0.4 a	0.5±0.0 a	21.4±0.7 a
Control	179.2±3.1 b	66.7±0.6 b	74.6±0.6 b	6.8±0.3 b	12.3±0.4 a	10.1±0.3 b	0.5±0.0 a	20.4±0.7 b
Storage duration (C)								
0 days	199.6±5.7 a	69.7±0.9 a	77.6±0.7 a	8.7±0.2 a	11.4±0.6 c	9.2±0.4 b	0.5±0.0 a	19.0±0.6 c
60 days	193.5±6.3 ab	69.7±1.2 a	76.6±0.8 a	6.8±0.2 b	13.2±0.4 a	10.7±0.1 a	0.5±0.0 a	21.4±0.4 b
120 days	184.7±5.6 b	66.5±1.2 b	74.4±1.1 b	6.0±0.3 c	12.4±0.4 b	10.9±0.5 a	0.5±0.0 a	22.3±1.2 a
ANOVA								
A	*	*	*	*	*	*	*	*
B	*	*	*	*	ns	*	ns	*
C	*	*	*	*	*	*	ns	*
A × B	*	*	*	ns	ns	*	ns	*
A × C	ns	ns	ns	*	*	*	*	*
B × C	ns	ns	ns	ns	*	*	*	*
A × B × C	ns	ns	ns	ns	ns	*	*	ns

SSC - total soluble solids; TS - total sugars; TA - titrable acidity; TS/TA – ratio between total sugars and total acids.

*Values within each column followed by the same small letter are not significantly different at $p \leq 0.05$ by Duncan's test; ns - non-significant differences

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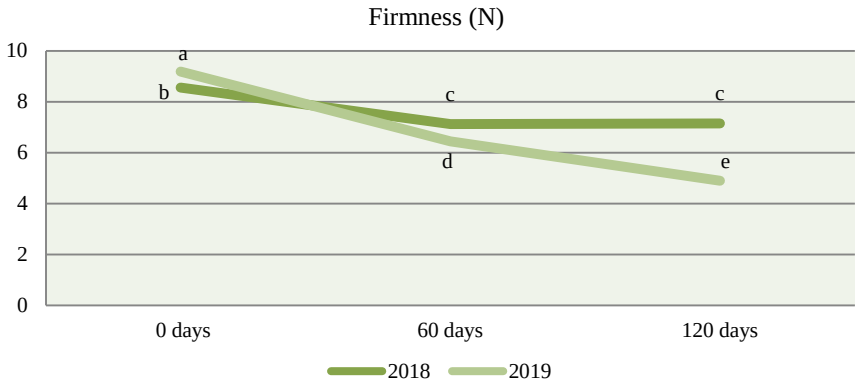

Figure 2. Interaction effect of year/storage duration on fruit firmness of apple 'Gloster'

Figure 2 shows the interaction effect of year and storage duration on the firmness of 'Gloster' apple fruits. The highest value was obtained for fruits sampled in 2019 and tested at harvest time (0 days), while the same fruits had the lowest firmness value after 120 days of storage. These results are consistent with the findings of Casero et al. (2004), who found that the application of calcium chloride reduces softening and maintains fruit firmness during storage. On the other hand, Baranyai et al. (2020) emphasized that as the storage period is extended, the firmness of apple fruits decreases, which is confirmed by the results of our research.

The results regarding the interaction effect between year and storage duration, as well as treatment and storage duration, on the soluble solids content of 'Gloster' apple fruits are presented in Figure 3. The highest value for this quality parameter was determined in 2019 after 60 days of storage, while the lowest value was observed in fruits sampled in 2018 at harvest time (0 days). On the other hand, when analyzing the results of the interaction effect between the treatment with the 'Stopit' product and storage duration, the highest values were found in the control after 60 days of storage, while the lowest values were observed in the same variant at harvest time (0 days). According to literature data, a soluble solids content of 11°Brix is considered a lower value to achieve optimal consumer acceptance (Magazin et al., 2013).

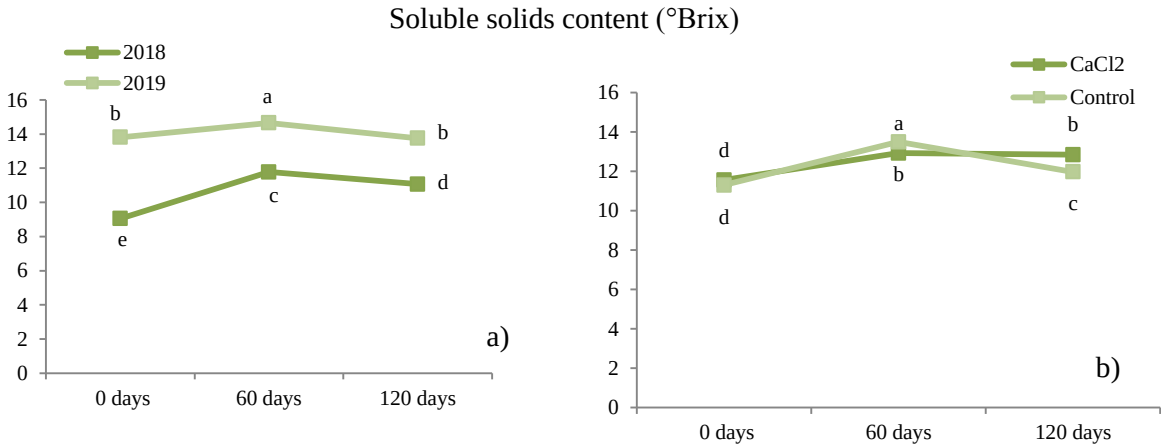

Figure 3. Interacion effects of year/storage duration (a) and treatment/storage duration (b) on the soluble solids content of apple 'Gloster'

The results of total sugar and acid content in 'Gloster' apple fruits, depending on the influence of year, treatment, and storage duration, are shown in Figure 4. The interaction effect of variability factors significantly influenced the total sugar content in 'Gloster' apple fruits (Figure 4a). The highest value for this parameter was recorded in 2019 for fruits treated with 'Stopit' product and stored for 120 days, while the lowest value was observed in both types of fruits (treated and untreated) in 2018, at harvest (0 days). Hudina and Štampar (2009) state that calcium content does not play a significant role in the sugar content of apple fruits; instead, sugar content depends on genotype, environmental factors, and agronomic practices. During storage, changes in sugar content occur due to increased starch degradation. According to Niketić-Aleksić (1994), the average total sugar content in apple fruits varies from 6.6% to 15.5%. The interaction of these variability factors also significantly influenced total acid content (Figure 4b). Control fruits tested in 2018 after 120 days of storage had the highest content, while fruits in the same year treated with calcium chloride and tested at harvest (0 days) had the lowest total acid content. Optimal calcium supply directly affects an increase in acid content in fruits, while during storage, these values decrease due to fruit respiration and organic acid degradation processes (Cheng et al., 2018).

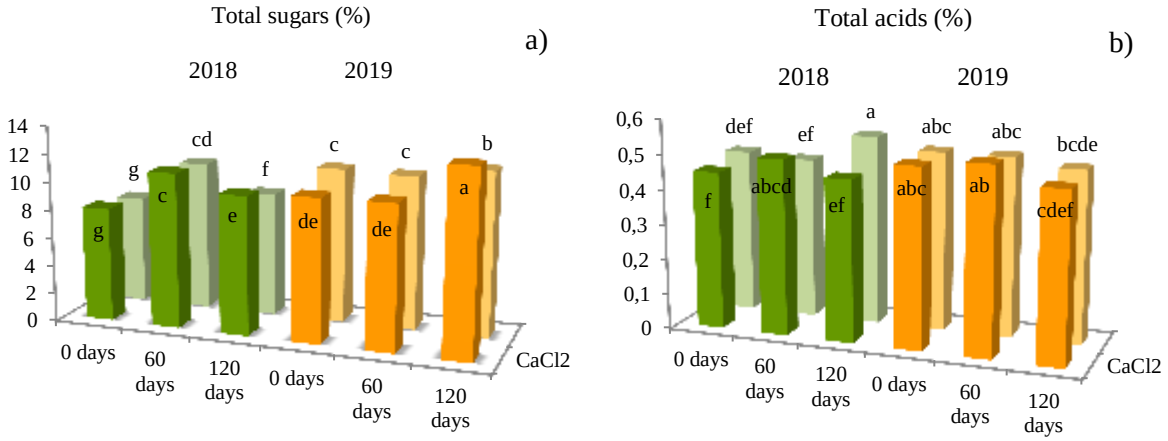

Figure 4. Interaction effects of year/treatment/storage duration on total sugars (a) and total acids (b) in the fruit of apple cultivar 'Gloster'

Figure 5 shows the interaction effect of year/treatment, year/storage duration, and treatment/storage duration on the sugar/acid ratio in 'Gloster' apple fruits. Higher values of this parameter were recorded in 2019 and in the treatment with the 'Stopit' product (Figure 5a). Furthermore, higher values were observed in 2019 after 120 days of fruit storage (Figure 5b). However, no consistent trend was observed in the values of the sugar/acid ratio across different storage duration and treatments (Figure 5c). In this regard, it is mentioned in the literature that calcium slows down the ripening and accumulation of sugars in apple fruits, resulting in increased sugar content and decreased acid content. However, during the storage period, sugar content increases while the acid content decreases, resulting in changes in sweetness index values (Kadir, 2005).

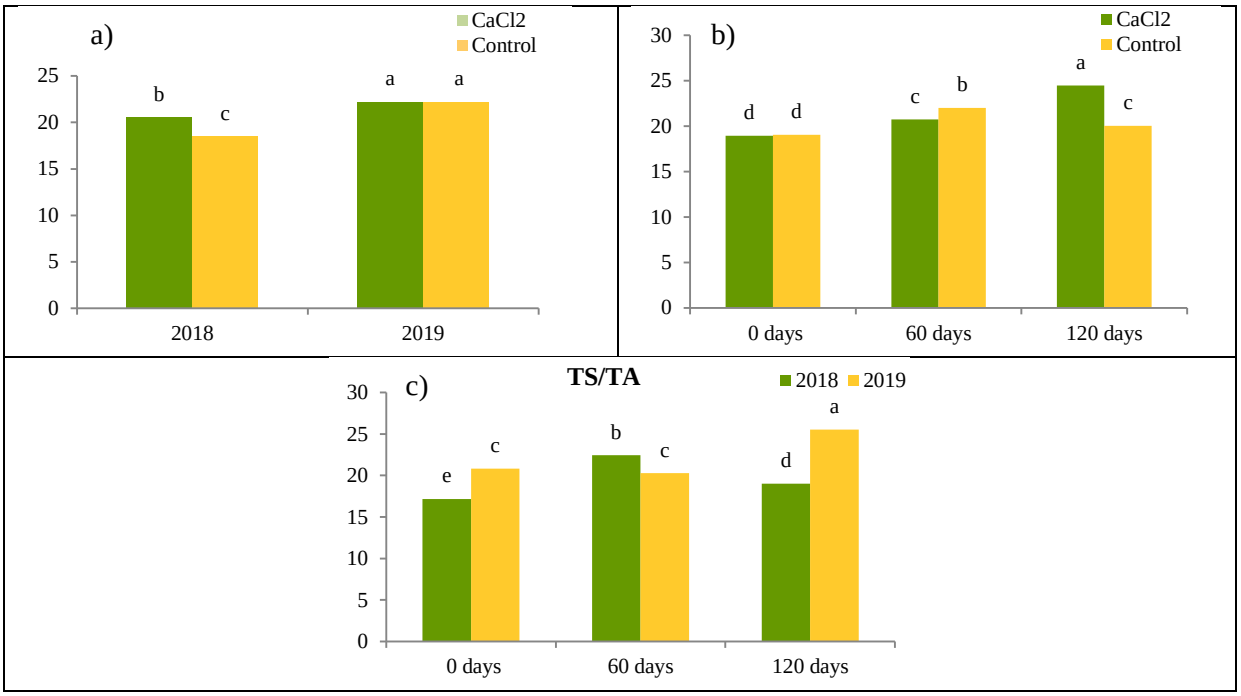

Figure 5. Interaction effects of year/treatment (a), treatment/storage duration (b), and year/ storage duration (c) on total sugars/total acids content of apple fruit of cutivar 'Gloster'

Conclusions

The results obtained indicate that foliar application of the 'Stopit' product based on calcium chloride during the growing season is an effective measure to reduce quality losses in 'Gloster' apple fruits during storage in normal atmosphere. In this regard, guidelines can be provided to producers for improving apple cultivation techniques through the application of the 'Stopit' product, aiming to obtain high-quality fruits without negatively affecting consumer acceptance.

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