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Analysis of Possibility to Apply Preharvest 1-Methylcyclopropene (1-MCP) Treatment to Delay Harvesting of Red Jonaprince Apples

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Abstract: The production of Red Jonaprince cultivar is increasing, but the quality of apples is still challenging. Therefore, various options may be used including 1-Methylcyclopropene (1-MCP) application, as it influences ethylene receptors and blocks them, resulting in the possibility of delaying harvesting. The preharvest application of 1-MCP has not been studied so far for this cultivar but for other ones it has been successful, as it is based on the understanding of the natural apple ripening process. The study aimed to analyze the possibility of applying a 1-MCP treatment in the preharvest period for Red Jonaprince apples. The study was conducted based on a comparison of apples from two groups of Red Jonaprince apple trees (4 years) cultivated in an experimental orchard, where for one of them 1-MCP was applied in the preharvest period (Harvista™; 150 g per ha; 20 September—12 days before the optimum harvesting window (OHW)). For both groups, the apples were studied twice, for harvesting in the OHW (2 October) and for delayed harvesting (24 October). The harvested fruits were stored in an Ultra Low Oxygen chamber (ULO; 1.2% CO_2, 1.2% O_2) until May. They were analyzed before storage (preharvest) five times (20 September–24 October) and after storage (postharvest) three times (20 March–18 May). The following parameters were included: firmness, total soluble solids (TSS) content, titratable acidity (TA). For the preharvest period, the parameters also included internal ethylene content (IEC), starch index, and Streif index. For the preharvest period, significant differences associated with the 1-MCP treatment ($p \leq 0.05$) were observed for the IEC (lower results for apples treated for 4th and 5th assessment), TA (higher results), and Streif index (higher results). Meanwhile, for firmness, TSS, and starch index for the majority of measurements there were no differences (p > 0.05). For the postharvest period, significant differences associated with 1-MCP treatment ($p \leq 0.05$) were observed for firmness (higher results) and TA (higher results) both for OHW and delayed harvesting. It was concluded that a preharvest 1-MCP treatment allowed delayed harvesting and reduced the quality deterioration during the ULO storage of Red Jonaprince apples.

Keywords: 1-methylcyclopropene; 1-MCP; preharvest; Red Jonaprince; quality

1. Introduction

When comparing apple production in Poland and other European Union countries, it must be indicated that some cultivars that are grown are equally popular in various countries. For European Union countries, Golden Delicious is the most widespread (15% of the European Union's total apple area), followed by Idared and Jonagold with its mutants (10% and 10%), as defined based on Eurostat data [1]. At the same time, based on the data of the Central Statistical Office in Poland [2] it may be stated that Idared (22% of the Polish total apple area) and Jonagold (17%) are also among the most prominent ones, but Golden Delicious is not so prominent.

The cultivars of Idared and Jonagold are characterized by various consumer characteristics and sensory features, as was proven in Polish studies by Adamczyk et al. [3], as Jonagold fruits are more juicy, aromatic, harder, sweeter, and of higher general quality than Idared fruits, which were more sour. However, during storage the sensory features of Jonagold apples significantly decrease compared with changes observed for Idared fruits [3]. It follows that there is a need of specific actions to preserve the quality features of Jonagold apples.

According to the Regulation of the Commission of the European Communities No 85/2004 of 15 January 2004, which lays down the marketing standard for apples [4], Jonagold/Jonagored is classified with its mutants, including Crowngold, Decosta, Jonabel, Jonagold 2000, Jonagored Supra, King Jonagold, and Red Jonaprince. The production of Red Jonaprince in European Union is rapidly increasing, and even the United States Department of Agriculture while presenting apple production in European Union indicates this specific mutant with Jonagold/Jonagored as a group of Jonagold/Jonagored/Red Jonaprince [5]. In Poland, it was observed that during the last 10 years, the production of this cultivar increased and even doubled during a single year [6], while for other countries the suitability of this cultivar for commercial growing has also been studied [7].

The production of Red Jonaprince is increasing, which is associated with its excellent fruit surface color and the fruit color intensity [8]. However, it is becoming challenging to improve the production process and consumer satisfaction [9]. Within this area, it has been studied how to provide such conditions of storage to obtain the best quality of fruits, and various storage conditions are now studied for this cultivar [10].

Among promising options to apply is the use of 1-Methylcyclopropene (1-MCP) during storage (postharvest), which has been proven to delay the softening of Red Jonaprince apples [11]. However, the 1-MCP was studied in the preharvest period as a novel option to maintain the eating quality [12] and enable delayed harvesting [13]. Its application is based on the understanding of the natural apple ripening process and inhibiting it by influencing ethylene receptors and blocking them, resulting in the possibility of delaying harvesting due to counteracting ethylene binding and its delayed action [14]. It would be especially beneficial to obtain a sustainable production of apples, based on recent research and in agreement with natural physiological mechanisms, to provide a high-quality product, reducing the costs and environmental impact of production. This option has so far been studied for Jonagold [15], but not for Red Jonaprince.

The study aimed to analyze the possibility of applying the 1-MCP treatment in the preharvest period for Red Jonaprince apples.

2. Materials and Methods

2.1. Experimental Procedures

The experiment was conducted in the facilities of the Department of Pomology and Horticulture Economics, including the experimental orchard and Ultra Low Oxygen chamber (ULO). For ULO chamber gas contents of 1.2% CO_2 and 1.2% O_2 were applied, similarly to the other studies [16], and the temperature of 1 °C also conformed. The experiment was conducted in 2017 (in orchard) and in the 2017/2018 storage season (in ULO chamber), according to similar experimental procedures to the previous experiments conducted for Szampion apples [13]. In the experimental orchard, described in our previous study [13], Red Jonaprince cultivar trees (4 years of age, 3 m tall) were used. The weather conditions for the experimental period were also described in our previous study [13].

The Red Jonaprince cultivar trees were divided into 2 groups, which were treated as a studied group (1-MCP applied before harvesting) and control group (1-MCP not applied). The 1-MCP was applied preharvest, while the dedicated sprayable formulation for horticultural products (Harvista™, AgroFresh Solutions Inc., Philadelphia, PA, USA) was used as a product for preharvest use. It was sprayed on the day of 20 September, 12 days before the optimum harvesting window (OHW) for Red Jonaprince cultivar in Poland (2 October). The applied dose was in agreement with the commonly applied doses, and the same as in our previous study [13]—namely 150 g per ha—while the solution was applied with 400 L of water in the morning.

For both groups, the apples were studied twice—while they were harvested in the OHW (2 October) and for delayed harvesting (24 October). The harvested apples were stored in a ULO chamber until May. They were analyzed before storage (preharvest) 5 times (20 September–24 October) and after storage (postharvest) 3 times (20 March–18 May), which corresponds with the dynamics of changes and processes in the indicated periods. The scheme of the experimental procedure is presented in Figure 1.

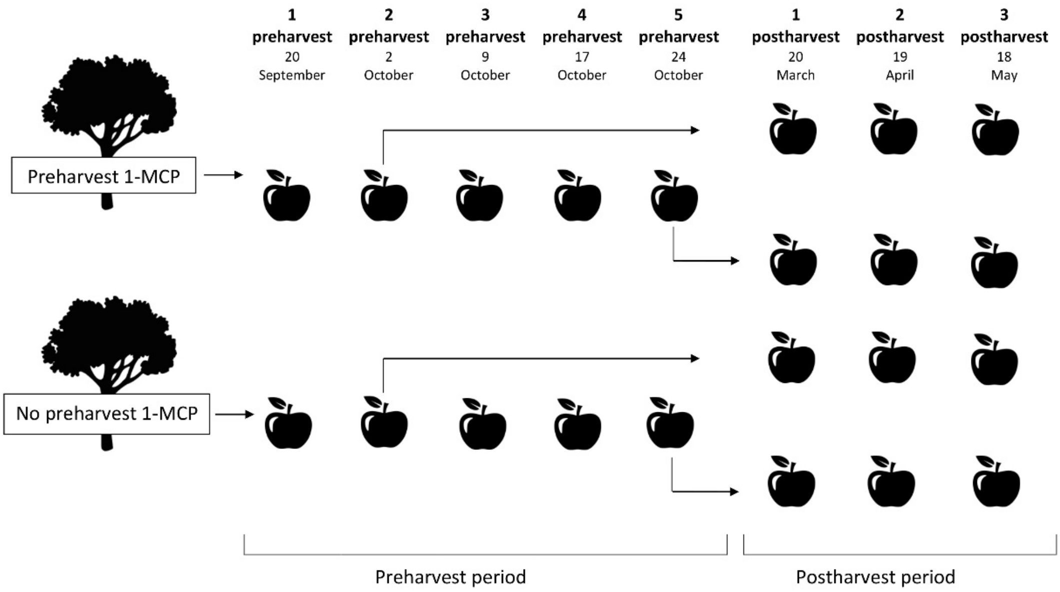

Figure 1. The scheme of the experimental procedure.

2.2. Measurements

When they were assessed in the preharvest period, the apples were studied to analyze their firmness, total soluble solids (TSS) content, titratable acidity (TA), internal ethylene content (IEC), starch index, and Streif index. When they were assessed in the postharvest period, the apples were studied to analyze their firmness, TSS content, and TA. The IEC, starch index, and Streif index were included only in the preharvest period, as those parameters are typical for this period as they are associated with the maturity of apples [17–19].

The firmness was expressed as N and assessed while a universal testing machine (Instron 5542, Instron, Norwood, MA, USA) was applied, with stainless steel plunger tips of 11 mm diameter and a speed of 4 mm/s. It was analyzed after the peel was removed, and the measurement was conducted independently for the two opposite sides of the fruit and replicated four times for each measurement.

The TSS content was expressed as °Bx and assessed while a digital refractometer (Atago Palette PR-32, Atago Co., Ltd., Tokyo, Japan) was applied for a pressed juice. The assessment was replicated four times for each measurement.

The TA was expressed after recalculation for malic acid content while an automatic titrator (TitroLine 5000, Xylem Analytics Germany GmbH, Weilheim, Germany) was applied for a pressed juice. It was titrated with NaOH (solution of 0.1 M) until obtaining pH of 8.1 and replicated four times for each measurement.

The IEC was expressed as µl/l and assessed while a gas chromatography (HP 5890, Hewlett Packard, Palo Alto, CA, USA) was applied. It was measured for the 1 ml of air samples collected using a syringe from the core space of the apples. The assessment was replicated four times for each measurement, and 10 apples were analyzed for each batch.

The starch index was expressed using a 10-point starch index scale, while the color of the flesh was compared visually with standards. It was measured after reaction with Lugol's iodine solution (I_3K). The assessment was replicated four times for each measurement, and 10 apples were analyzed for each batch.

The Streif index was calculated based on a commonly applied equation, while the firmness, TSS content, and starch index were included [19].

2.3. Statistical Analysis

The statistical analysis was conducted after verifying the data distribution (the Shapiro–Wilk test). The data were analyzed while applying the Student's t-test (in the case of normal distributions) and the Mann–Whitney U test (in the case of distributions different from normal). Statistical significance was attributed to values of $p \leq 0.05$. The statistical analysis was performed with the Statgraphics Plus for Windows 5.1 (Statgraphics Technologies Inc., The Plains, VA, USA).

3. Results

The firmness of Red Jonaprince in the preharvest and postharvest periods in the conducted experiment is compared in Table 1. For the preharvest period, significant differences between apples treated with 1-MCP and the control apples were observed exclusively for the fifth assessment (higher results for the 1-MCP ones). For the postharvest period, significant differences between apples treated with 1-MCP and the control apples were observed for the second and third assessment (for OHW harvesting), as well as the first and third assessment (for delayed harvesting). A higher firmness for Red Jonaprince cultivar apples treated with 1-MCP after harvesting was observed for all the periods of storage, regardless of the harvesting time.

Table 1. The firmness [N] of Red Jonaprince in the preharvest and postharvest periods in the conducted experiment.

Assessment	No preharvest 1-MCP Treatment		Preharvest 1-MCP Treatment		*p*-Value
	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	
First preharvest	69.2 ± 1.0	69.5 (67.8–70.0)	69.8 ± 1.2	69.4 (68.9–71.4)	0.4631
Second preharvest	70.5 ± 2.2	70.2 (68.2–73.4)	67.8 ± 2.3	67.8 (65.7–69.9)	0.1368
Third preharvest	66.5 ± 0.6	66.6 (65.7–67.2)	67.2 ± 2.4	67.8 (63.8–69.2)	0.6275
Fourth preharvest	67.8 ± 2.3	67.0 (66.3–71.1)	67.9 ± 0.8	67.8 (67.1–69.1)	0.9363
Fifth preharvest	63.4 ± 0.3	63.4 (63.0–63.8)	65.9 ± 0.4	65.8 (65.5–66.4)	<0.0001
Harvesting in optimum harvesting window					
First postharvest	67.5 ± 2.7	67.3 * (64.4–71.0)	69.4 ± 2.1	69.4 (67.5–71.2)	0.0833
Second postharvest	60.1 ± 3.8	61.4 (54.5–63.1)	70.1 ± 1.7	70.3 (68.2–71.8)	0.0029
Third postharvest	62.5 ± 2.4	62.8 (59.4–65.2)	70.4 ± 2.4	70.4 (67.6–73.4)	0.0034
Delayed harvesting					
First postharvest	54.5 ± 1.0	54.5 (53.4–55.4)	61.9 ± 1.4	61.5 (60.6–63.9)	0.0001
Second postharvest	56.6 ± 4.8	55.8 (51.7–63.3)	61.9 ± 5.0	61.9 (57.2–66.5)	0.1828
Third postharvest	45.5 ± 4.4	45.1 (41.3–50.6)	63.1 ± 0.6	63.4 (62.3–63.5)	0.0002

* distribution different from normal (Shapiro–Wilk test applied for verification; $p \leq 0.05$); 1-MCP – 1-methylcyclopropene.

The TSS contents for Red Jonaprince in the preharvest and postharvest periods in the conducted experiment are compared in Table 2. For the preharvest period, significant differences between the apples treated with 1-MCP and the control apples were observed exclusively for the third assessment (lower results for 1-MCP ones). For the postharvest period, no significant differences between the apples treated with 1-MCP and the control apples were observed.

Table 2. The total soluble solids (TSS) content [°Bx] for Red Jonaprince in the preharvest and postharvest periods in the conducted experiment.

Assessment	No preharvest 1-MCP Treatment		Preharvest 1-MCP Treatment		*p*-Value
	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	
First preharvest	12.8 ± 0.5	12.8 (12.2–13.4)	12.9 ± 0.2	12.9 * (12.7–13.1)	1.0000
Second preharvest	13.7 ± 0.2	13.7 (13.4–13.9)	13.4 ± 0.2	13.4 (13.2–13.6)	0.0871
Third preharvest	13.3 ± 0.3	13.3 (12.9–13.5)	13.2 ± 0.3	13.1 (13.0–13.7)	0.0293
Fourth preharvest	13.6 ± 0.2	13.5 (13.4–13.8)	13.1 ± 0.4	13.1 (12.7–13.5)	0.0659
Fifth preharvest	14.2 ± 0.3	14.1 (13.9–14.5)	13.7 ± 0.4	13.8 * (13.2–14.1)	0.1123
Harvesting in optimum harvesting window					
First postharvest	13.7 ± 0.4	13.6 (13.3–14.2)	13.2 ± 1.1	13.1 (12.0–14.5)	0.4447
Second postharvest	12.9 ± 0.2	12.9 (12.6–13.1)	12.9 ± 0.4	12.8 (12.6–13.5)	0.9190
Third postharvest	13.7 ± 1.0	13.6 (12.7–14.7)	13.5 ± 0.6	13.5 (12.7–14.1)	0.7437
Delayed harvesting					
First postharvest	13.2 ± 0.5	13.4 (12.5–13.7)	13.6 ± 0.6	13.6 (12.9–14.2)	0.3809
Second postharvest	13.4 ± 0.5	13.2 (13.1–14.1)	13.7 ± 0.2	13.7 * (13.5–14.0)	0.2454
Third postharvest	13.0 ± 0.5	13.0 (12.4–13.5)	12.9 ± 0.3	12.8 (12.6–13.3)	0.7985

* distribution different from normal (Shapiro–Wilk test applied for verification; $p \leq 0.05$); 1-MCP – 1-methylcyclopropene.

The TAs for Red Jonaprince in the preharvest and postharvest periods in the conducted experiment are compared in Table 3. For the preharvest period, significant differences between the apples treated with 1-MCP and the control apples were observed for the second, third, and fourth assessment (higher results for 1-MCP ones). For the postharvest period, significant differences between the apples treated with 1-MCP and the control apples were observed for the third assessment (both for OHW harvesting and delayed harvesting), and a higher TA for the apples treated with 1-MCP was stated.

Table 3. The titratable acidity for Red Jonaprince in the preharvest and postharvest periods in the conducted experiment.

Assessment	No preharvest 1-MCP Treatment		Preharvest 1-MCP Treatment		*p*-Value
	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	
First preharvest	0.608 ± 0.058	0.622 (0.528–0.663)	0.616 ± 0.026	0.614 (0.591–0.644)	0.8262
Second preharvest	0.556 ± 0.009	0.552 (0.549–0.569)	0.602 ± 0.025	0.595 (0.579–0.638)	0.0133
Third preharvest	0.581 ± 0.020	0.586 (0.555–0.596)	0.642 ± 0.040	0.637 (0.607–0.688)	0.0340
Fourth preharvest	0.518 ± 0.054	0.507 (0.467–0.589)	0.610 ± 0.017	0.611 (0.591–0.627)	0.0170
Fifth preharvest	0.568 ± 0.016	0.566 (0.552–0.590)	0.555 ± 0.032	0.542 (0.534–0.603)	0.4957
Harvesting in optimum harvesting window					
First postharvest	0.548 ± 0.033	0.539 (0.520–0.596)	0.527 ± 0.061	0.542 (0.441–0.582)	0.5616
Second postharvest	0.465 ± 0.014	0.463 (0.451–0.483)	0.485 ± 0.066	0.498 (0.395–0.549)	0.5752
Third postharvest	0.387 ± 0.019	0.392 (0.362–0.403)	0.429 ± 0.012	0.432 (0.413–0.440)	0.0100
Delayed harvesting					
First postharvest	0.400 ± 0.051	0.399 (0.353–0.450)	0.477 ± 0.058	0.475 (0.416–0.541)	0.0960
Second postharvest	0.380 ± 0.053	0.397 (0.302–0.423)	0.408 ± 0.017	0.411 (0.386–0.425)	0.3426
Third postharvest	0.283 ± 0.024	0.291 (0.248–0.301)	0.372 ± 0.014	0.374 (0.354–0.387)	0.0007

1-MCP – 1-methylcyclopropene.

The IECs for Red Jonaprince in the preharvest period in the conducted experiment are compared in Table 4. Significant difference between the apples treated with 1-MCP and the control apples was observed for the third, fourth, and fifth assessment. A higher IEC was observed for apples treated with 1-MCP for the third assessment, while a lower was observed for the fourth and fifth assessments.

Table 4. The internal ethylene content [µl/l] for Red Jonaprince in the preharvest period in the conducted experiment.

Assessment	No Preharvest 1-MCP Treatment		Preharvest 1-MCP Treatment		p-Value
	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	
First preharvest	0.165 ± 0.156	0.115 * (0.052–0.861)	0.153 ± 0.161	0.105 * (0.050–0.842)	0.1744
Second preharvest	0.281 ± 0.444	0.109 * (0.061–2.030)	0.236 ± 0.337	0.123 * (0.020–1.420)	0.9440
Third preharvest	0.138 ± 0.112	0.113 * (0.053–0.710)	0.142 ± 0.046	0.135 (0.055–0.287)	0.0431
Fourth preharvest	1.563 ± 3.596	0.309 * (0.020–20.200)	0.114 ± 0.155	0.063 * (0.010–0.898)	<0.0001
Fifth preharvest	5.751 ± 12.343	0.710 * (0.051–68.400)	0.759 ± 1.800	0.201 * (0.065–8.180)	<0.0001

* distribution different from normal (Shapiro–Wilk test applied for verification; $p \leq 0.05$); 1-MCP – 1-methylcyclopropene.

The starch indexes for Red Jonaprince in the preharvest period in the conducted experiment are compared in Table 5. A significant difference between the apples treated with 1-MCP and the control apples was observed for the fourth assessment (lower results for 1-MCP ones).

Table 5. The starch index for Red Jonaprince in the preharvest period in the conducted experiment.

Assessment	No preharvest 1-MCP Treatment		Preharvest 1-MCP Treatment		p-Value
	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	
First preharvest	6.9 ± 1.7	7 * (3–9)	6.8 ± 1.8	7 * (4–9)	0.8286
Second preharvest	9.1 ± 1.3	9.5 * (5–10)	9.1 ± 1.1	9 * (6–10)	0.8367
Third preharvest	9.5 ± 1.5	10 * (1–10)	9.7 ± 0.6	10 * (8–10)	0.9578
Fourth preharvest	10 ± 0.0	10 * (10–10)	9.4 ± 1.5	10 * (1–10)	0.0146
Fifth preharvest	10 ± 0.0	10 * (10–10)	9.9 ± 0.3	10 * (9–10)	0.5637

* distribution different from normal (Shapiro–Wilk test applied for verification; $p \leq 0.05$); 1-MCP – 1-methylcyclopropene.

The Streif indexes for Red Jonaprince in the preharvest period in the conducted experiment are compared in Table 6. A significant difference between the apples treated with 1-MCP and the control apples was observed for the fourth and fifth assessment (higher results for 1-MCP ones).

Table 6. The Streif index for Red Jonaprince in the preharvest period in the conducted experiment.

Assessment	No Preharvest 1-MCP Treatment		Preharvest 1-MCP Treatment		p-Value
	Mean ± SD	Median (Range)	Mean ± SD	Median (Range)	
First preharvest	0.079 ± 0.003	0.079 (0.076–0.082)	0.080 ± 0.006	0.079 (0.075–0.088)	0.6913
Second preharvest	0.057 ± 0.004	0.058 (0.052–0.060)	0.056 ± 0.002	0.056 (0.053–0.057)	0.4939
Third preharvest	0.053 ± 0.003	0.052 (0.050–0.058)	0.052 ± 0.002	0.053 (0.050–0.054)	0.8103
Fourth preharvest	0.050 ± 0.002	0.050 (0.048–0.053)	0.055 ± 0.002	0.054 (0.053–0.059)	0.0144
Fifth preharvest	0.045 ± 0.001	0.045 (0.044–0.046)	0.048 ± 0.001	0.048 (0.047–0.050)	0.0140

1-MCP – 1-methylcyclopropene.

4. Discussion

Applying 1-MCP for different types of fruits was proven to slow down its ripening, as was stated for mango [20], avocado, papaya, apples [21], bananas [22], and other fruits. However, the majority of studies analyzed the effect of the 1-MCP application after harvesting time, while only a few studies analyzed the possibility of applying the 1-MCP treatment to influence the fruit before harvesting [13]. For cantaloupe, a preharvest treatment slightly delayed its maturity and improved early harvest synchrony [23]. For pears, the preharvest treatment reduced the incidence of premature fruit drop [24]. For tomatoes, the preharvest treatment reduced the ethylene production and respiration rate of the fruit harvested at mature-green and full-red stages of maturity, which resulted in a reduction in natural weight loss during storage [25].

Taking into account a wide range of positive effects, the preharvest 1-MCP application may be beneficial and should be studied for various fruits. Apple was the first crop for which 1-MCP was commercially used on a large scale, as for this fruit limited ripening after harvest is highly desirable [26]. For apples, it was concluded that 1-MCP application may be an effective method for the management of their condition, storability, and post-storage fruit quality, but important factors determine the final effect that is observed [27]. In our previous study, it was stated that 1-MCP is beneficial for the quality of the Szampion apples, but also allow delayed harvesting, as without preharvest 1-MCP application, almost 90% of the apples fell from the trees before the planned delayed harvesting [13]. In the presented study conducted for Red Jonaprince apples, delayed harvesting was possible also without 1-MCP application, but the quality features of the apples were influenced by the applied treatment.

In the conducted study, for the preharvest period significant differences associated with 1-MCP treatment were observed for IEC (lower results for apples treated for the fourth and fifth assessment). Such observation is typical, as lower IEC results from the reduced ethylene production, being a direct effect of 1-MCP application [28]. This was observed also in other studies for Scarletspur Delicious [29] and Fuji cultivars [30].

The other observations indicated in the conducted study for the preharvest period were higher results for the TA and Streif index, while for firmness, TSS, and starch index for majority of measurements there were no differences. Additionally, the mentioned influences stated for the TA and Streif index are supposed, in agreement with results of other studies, to result from delayed ripening. The same observations in the case of TA were indicated for Szampion [13], Gamhong [31], and Fuji cultivars [30]. In the case of the Streif index, the observed association is not surprising, as this factor is a typical indicator of fruit maturity [32].

In the conducted study, for the postharvest period significant differences associated with 1-MCP treatment were observed for firmness and TA, as both for OHW and delayed harvesting the higher results were observed when 1-MCP was applied. The observations for firmness are similar as those stated in the preharvest period, and are in agreement with the results of other studies for Szampion [13], McIntosh [33], and Gala [34].

All the mentioned observations indicate that a preharvest 1-MCP application allows us to obtain a more flexible harvesting time (it may be either in the planned OHW or delayed), and in both cases, the quality of fruits is higher than in case of not applying the 1-MCP. The other benefit is associated with the fact that when 1-MCP is applied, the storage time may be prolonged without the quality decreasing, which is a typical problem for Jonagold cultivars [3].

While sustainable apple production is taken into account, it should be emphasized that the events observed during recent weeks associated with the Coronavirus Disease 2019 (COVID-19) pandemic situation have revealed that all aspects of human life, including agriculture and food systems, are highly dependent on planned actions such as harvesting time and storage period. In terms of sustainable production, such a situation may contribute to the effects of increasing waste if there are forced periods of reduced production. Taking this into account, some actions must be considered to deal with the lower availability of seasonal workers, as for this sector remote work is not a viable option [35]. One of the possible solutions in such situation would be using 1-MCP, which not only increases the quality of fruits but also allows an adjustable production plan.

As was proven in the presented experiment, 1-MCP applied directly on the apple tree could effectively slow down the ripening process and fruit senescence. 1-MCP allows us to obtain significant benefits, as it protects plant products from both endogenous and exogenous sources of ethylene. It is a natural option [36], as it may be applied with respect to the natural processes of fruit maturation and may be an element of balanced production to obtain a higher quality of product and other profits for producers.

5. Conclusions

We compared apples after 1-MCP treatment and without it for the preharvest period, and significant differences associated with 1-MCP treatment were observed for the IEC (lower results for apples treated), TA (higher results), and Streif index (higher results), while for the firmness, TSS, and starch index, for the majority of measurements there were no differences. For the postharvest period, significant differences associated with 1-MCP treatment were observed for the firmness (higher results) and TA (higher results) both for OHW and delayed harvesting. The 1-MCP treatment applied before harvesting allowed a delayed harvesting and reduced the quality deterioration during the ULO storage of Red Jonaprince apples.

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