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Effect of Oxygen and Carbon Dioxide Concentration on the Quality of Minikiwi Fruits after Storage

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Abstract: The rapid increase in the production of hardy kiwi fruit (*A. arguta*) since the beginning of the 21st century has required the development of new cultivation technologies and postharvest handling procedures in order to extend the supply and transport of the fruit to distant markets. Fruit storage focuses on the inhibition of ripening processes regulated by ethylene activity or respiration. Both of these are effectively regulated by appropriate concentrations of O_2 and CO_2 in the atmosphere surrounding the fruit. In this study, the effect of the concentration of both gases in the cold room on the physico-chemical indices of fruit quality, i.e., mass loss, firmness, soluble solids and monosaccharides content, titratable acidity and acid content, and color of the peel was evaluated. Studies have shown that high CO_2 concentrations inhibit ripening processes more effectively than low O_2 concentrations. Softening of berries as well as an increase in soluble solid contents was recorded during the first 4 weeks of storage in the fruit. However, the increase in monosaccharides was fairly stable throughout the study period. The increase in soluble solids content as well as the loss of acidity were more strongly determined by CO_2 than O_2, although the acid content in a 10% CO_2 atmosphere did not change. Additionally, the fruits were greener after storage in 10% CO_2, but the weakness was skin dulling and darkening. The results indicate that the use of high CO_2 concentrations (5–10%) effectively inhibits ripening processes in fruit. After 12 weeks of storage, the fruit was still not suitable for direct consumption, which suggests that the storage period can be extended further.

Keywords: controlled atmosphere; ultra-low oxygen; storage; fruit quality; minikiwi

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1. Introduction

Growing interest in the cultivation of *Actinidia arguta* ((Sieb. & Zucc.) Planch. ex Miq.) in Europe has been observed since the beginning of the 21st century [1]. It is related to the high nutritional value of the fruit and the high productivity. These fruits, only a few centimeters long, are characterized by a unique taste and aroma, which arouses the curiosity of a growing group of consumers [2]. The productivity of this creeper was noticed over 1000 years ago in Asia [3]. The fruits of minikiwi are primarily characterized by a high content of vitamin C and significant antioxidant levels from the groups of carotenoids and flavonoids [4,5]. Berries are a rich source of minerals such as phosphorus, potassium, and calcium, as well as other vitamins PP, A, B1, and B2 [6,7]. *Actinidia arguta* shrubs tolerate the climatic conditions of Central and Eastern Europe due to their high frost resistance [8]. The dynamically developing minikiwi plantations in Europe require the development of new cultivation technologies.

Until now, research has focused on agrotechnical aspects, i.e., proper fertilization [9], keeping plants [10], or searching for new, valuable varieties [11]. Currently, an important issue is the optimization of the fruit storage conditions and supply. Thus far, assessing the aspects of the physiological ripening of fruits, the appropriate moment of maturity has been determined in which the fruits should be harvested [11–13]. However, minikiwi fruits have a relatively low storage ability under refrigerated conditions. The main reason is not fungal or physiological diseases, but the quick softening of fruit stored in a common cold store [14,15]. Appropriate storage conditions limit the ripening processes in fruit [16,17]. This applies to both the storage temperature and the composition of gases in the environment around the fruit. Inhibition of the respiration process by lowering the oxygen concentration positively affects the inhibition of processes related to fruit ripening, such as ethylene production, loss of firmness, decomposition of polysaccharides to monosaccharides, and degradation of chlorophyll [18–20]. Minikiwi is a climacteric fruit; therefore, endogenous ethylene, even in small amounts, activates the enzymes exo-polygalacturonase, endopolygalacturonase, pectin esterase, and endo-1,4-β-D-glucanase, contributing to the reduction in firmness [18,21]. Lack of care for appropriate storage conditions is the cause of the rapid loss of quality by fruit [22]. Too much carbon dioxide and too little oxygen can seriously damage the skin and flesh of the fruit. Critically low O_2 concentrations lead to fruit fermentation. According to Schlie et al. [23], at an O_2 concentration below 0.3–0.6%, the process of anaerobic respiration takes place—alcoholic fermentation. This gas composition causes irreversible damage to the fruit.

Research on the storage of kiwi (*A. deliciosa*) in low-oxygen compositions (O_2 = 05–1.0%) was carried out at the end of the 20th century [24]. The results of the research indicated that storing kiwis in 1% O_2 quite effectively inhibits the ripening of the fruit. It turned out, however, that oxygen content at the level of 0.5% can cause fermentation in the fruit, which was confirmed by the higher ethanol content in the flesh, especially in fruits that are more mature during the harvest, i.e., harvested with an extract content above 10° Brix. ULO (ultra-low oxygen) or DCA (dynamic controlled atmosphere) technologies allow a reduction in the content of oxygen to a very low level. The practical use of these technologies is justified, as research shows [25] that lowering the O_2 content to 1.5% enables the storage of minikiwi for up to 2 months in cold store conditions.

Lowering the O_2 content to the limit just above anaerobic respiration is most effective in inhibiting the ripening of pome fruits such as apples [26]. DCA technology is based on measurements of the intensity of carbon dioxide released in the processes of respiration, ethanol release, or chlorophyll fluorescence. Fruits react to stress caused by oxygen deficiency and switch from aerobic to anaerobic respiration. This reaction is best determined by monitoring chlorophyll fluorescence or ethanol synthesis. This technology is used only in technologically advanced farms, because improper use may damage the entire batch of stored fruit. On the other hand, the research to date by Hertog et al. [27] showed that fruit stored in an atmosphere with a low carbon dioxide content, close to zero, had a firmness 15 N lower than fruit stored in an atmosphere with a 5% CO_2 concentration. The essence of storage is to determine the composition of the atmosphere with the lowest possible concentration of O_2 and the highest possible concentration of CO_2 which does not damage the fruit tissue.

The aim of the study was to attempt to assess the influence of variable parameters of O_2 and CO_2 concentrations on the basis of various storage technologies on the quality of the minikiwi fruits. The study tried to demonstrate the physiological changes occurring in the fruit during storage, caused by ultra-low oxygen concentrations or high concentrations of carbon dioxide. The practical aspect was to demonstrate the most effective storage technology for minikiwi fruit in order to extend the supply of fruit in global markets.

2. Materials and Methods

2.1. Outline of the Experiment

Fruits collected from 8-year-old *A. arguta* vines were used for the research. Hardy kiwi fruits were manually harvested to plastic high vented containers from the experimental field of the Department of Pomology and Horticultural Economics, Warsaw University of Life Sciences (WULS-SGGW), located in Warsaw, central Poland (52.259° N, 21.020° E). The storage quality was assessed for two varieties, i.e., 'Geneva', an early variety of minikiwi, commonly grown in Poland [28], and 'Ananasnaya', the basic cultivar grown in the United States and which is the most widely grown minikiwi fruit in the world [29]. During harvesting, the fruits of both varieties were sorted, discarding fruits that differed in size (small) and had visible quality defects. The fruit was harvested at the harvest maturity phase determined on the basis of the soluble solids content (SSC), a method commonly used in commercial minikiwi plantations. The fruits were harvested once at a SSC content of 6–7° Brix. This value has been suggested by other authors [11,30] as an appropriate value for the harvest of minikiwis for storage. The collections were carried out on the dates:

- 'Geneva'—29th of August, 2017;
- 'Anansnaya'—15th of September, 2017;
- 'Geneva'—25th of August, 2018;
- 'Anansnaya'—14th of September, 2018.

Immediately after harvesting, the fruit was transported to the experimental cooler of the Department of Horticulture and Horticulture Economics and stored in 1 m^3 experimental chambers. The containers were equipped with an automatic Oxystat 200 system (David Bishoop Ltd., Heathfield, United Kingdom), ensuring the continuous monitoring of CO_2 and O_2 contents, and Handy PEA fluorimeters (Hansatech Industries Ltd., Pentney, United Kingdom) to assess chlorophyll fluorescence. Instrument calibration was performed automatically with a calibration gas mixture every 48 h.

The fruit was stored at 1 °C and about 90–95% relative air humidity. For the evaluation of the storage quality of the minikiwi, four gas mixtures corresponding to three storage technologies were used, i.e., controlled atmosphere (CA), ultra-low oxygen (ULO), and dynamic controlled atmosphere (DCA). Under CA conditions, two combinations of air composition were used, i.e., CA1 with 5% CO_2:1.5% O_2 and CA2 with 10% CO_2:1.5% O_2. Under ULO conditions, the composition of the atmosphere was 1.5% CO_2:1.5% O_2. On the other hand, in DCA conditions, the composition of the atmosphere was dynamically maintained at the level of about 0.4% CO_2 and about 0.4% O_2, changing the oxygen content in periods of fruit stress by 0.1%. Fruit stress in DCA was identified by chlorophyll fluorescence. The combinations of air compositions used in this study were determined based on previous studies [11,14,25]. To date, the effect of the evaluated O_2 and CO_2 concentrations on the ripening process of minikiwi during storage has not been described. The stored fruit analyses were conducted 7 times, i.e., directly after harvest, and then every 14 days for 12 weeks of storage. The experiment was replicated three times, each on 0.5 kg of fruit (approx. 70–80 fruits). To evaluate peel color changes and mass loss during the storage, additional fruits (30 fruits per replicate) were used and the measurements were always made on the same fruit.

2.2. Analytical Methods

All reagents were of analytical purity gradients or HPLC-grade and purchased from Sigma-Aldrich (Poznań, Poland) or Merck (Warsaw, Poland).

The fruit firmness (FF) was determined as a value of the force necessary for penetration of the fruit by a 4.5 mm diameter punch probe. FF was determined on 20 fruits in 3 replicates using an Instron 5542 penetrometer (Instron, High Wycombe, UK). Each fruit was subjected two times (on opposite sides, without peel removal), with a compression speed of 240 mm^{-1} during penetration to a depth of 5 mm. FF was expressed in Newtons (N).

The soluble solids content (SSC) was determined refractometrically, according to the Polish Standard PN-EN 12143:2000 [31] (developed by the Polish Committee of Standardization) in the juice squeezed out from 20 fruits. A PR-32 alpha digital refractometer (Atago, Tokyo, Japan) was used to assess SSC in juice, at 20 °C. Results were expressed in ° Brix. The titratable acidity (TA) was determined according to the Polish Standard PN-EN 12147:2000 [32]. TA was measured in water extracted from an average sample of 20 minced fruits by titrating with 0.1 N sodium hydroxide (NaOH) to the endpoint of pH 8.1, using a TitroLine 5000 system (Si Analytics, Mainz, Germany). The results were expressed as the percentage of anhydrous citric acid. Sugars and organic acids were determined by HPLC-RI, as described previously by Zielinski et al. [33], and expressed as grams of total sugar content or organic acid per 100 g fresh weight (F.W.). Color was measured in the center of the flat surface of 30 fruits using a Minolta CM-501i spectrophotometer (Minolta, Tokyo, Japan) equipped with a 5 mm measuring head and observer 10° and illuminant D65. The meter was calibrated using the manufacturer's standard white plate. Color changes were quantified in the L*, a*, and b* color space. Hue angle [(h° = $\tan^{-1}$ (b*/a*) + 180°) when a* < 0 and b* > 0] and chroma values [C = (a* 2 + b* 2)1/2] were calculated from a* and b* values. Hue angle values refer to a color wheel. Red, yellow, green, and blue colors were at angles of 0°, 60°, 120°, and 240°, respectively. Chroma describes the vividness or dullness of fruit color and also is known as a color saturation.

Mass loss was measured in three replicates of thirty fruits per treatment. Fruits were weighed at the beginning of the experiment and at various times during the course of the storage period, and the results were expressed as the percentage loss of initial mass.

2.3. Statistical Analysis

The results were analyzed statistically in the Statistica 12.5 program (StatSoft Polska, Krakow, Poland) using a two-way analysis of variance. A Newman–Keuls test was used for evaluating the significance of differences between the means, accepting the significance level as 5%.

3. Results

Firmness is one of the most important quality features of minikiwi fruit. The fruit after harvest was significantly different in firmness, and 'Ananasnaya' was almost two times harder than 'Geneva'. The experiment showed a significant effect of the oxygen and carbon dioxide contents in the atmosphere surrounding the fruit on its firmness. The research showed that the high CO_2 content was more effective in inhibiting the softening of blueberries than the lowered oxygen content (Table 1). In both years of research, after 2 weeks, a significant reduction in FF was observed, regardless of the storage technology used. However, in the following days, the softening process was much slower with the CO_2 contents of 5% and 10%. In the first year of research, after 8 weeks of storage in DCA and ULO, the FF decreased to the level characterizing the fruit as suitable for consumption (below 5 N), although in the following year, the softening processes in DCA and ULO progressed slightly slower. The fruits stored in CA1 and CA2 retained their firmness for much longer in both years. It is worth noting that even after 12 weeks of storage in a high concentration of CO_2, the firmness of the berries exceeded 2–3 times the firmness acceptable by consumers, especially after storage at a concentration of 10% CO_2. Interestingly, after 12 weeks of storage in CA2, the firmness value for both varieties was at a quite similar level (10–14 N), regardless of the firmness that the fruits exhibited immediately after harvest, i.e., 'Geneva' 34–36 N, and 'Ananasnaya' 53–54 N.

Table 1. Changes in firmness (N) measured in 'Geneva' and 'Ananasnaya' minikiwi fruit in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Geneva							
0	34.5 ± 1.4				36.3 ± 0.3			
2	32.0 ± 0.2	26.4 ± 1.6	32.9 ± 2.5	31.7 ± 1.3	34.6 ± 0.7	27.8 ± 1.6	35.6 ± 1.9	33.9 ± 1.5
4	13.5 ± 2.7	15.3 ± 1.9	23.6 ± 1.1	23.2 ± 1.1	15.7 ± 2.8	20.3 ± 2.8	25.7 ± 0.9	25.5 ± 0.7
6	8.2 ± 0.6	8.2 ± 1.1	19.2 ± 0.4	22.2 ± 1.1	9.77 ± 1.8	12.3 ± 1.3	23.1 ± 0.2	24.6 ± 0.6
8	4.0 ± 0.3	3.0 ± 0.3	13.9 ± 1.7	16.6 ± 2.1	8.70 ± 0.5	8.57 ± 1.2	17.8 ± 1.2	19.7 ± 3.1
10	2.1 ± 0.5	2.0 ± 0.3	6.9 ± 1.2	14.6 ± 2.2	6.00 ± 1.5	5.50 ± 0.7	12.4 ± 0.8	16.7 ± 1.9
12	1.9 ± 0.7	1.7 ± 0.2	6.8 ± 1.6	13.7 ± 1.2	3.73 ± 0.7	3.57 ± 0.4	9.00 ± 1.6	12.5 ± 1.1
Average	13.7 a	13.0 a	19.7 b	22.3 c	16.4 a	16.3 a	22.8 b	24.2 b
Significance	**	**	**	**	**	**	**	**

Table 1. *Cont.*

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	**ULO**	**CA1**	**CA2**	**DCA**	**ULO**	**CA1**	**CA2**
	Ananasnaya							
0	53.6 ± 1.37				54.6 ± 1.1			
2	29.3 ± 3.9	17.2 ± 0.9	32.0 ± 5.5	49.5 ± 2.1	30.4 ± 2.6	18.3 ± 1.1	31.9 ± 4.9	49.0 ± 1.9
4	16.8 ± 2.2	10.3 ± 1.4	21.0 ± 3.1	42.3 ± 1.0	16.7 ± 1.8	10.6 ± 0.8	21.3 ± 2.1	42.6 ± 0.9
6	9.8 ± 0.6	6.6 ± 0.7	15.1 ± 1.4	36.9 ± 2.6	10.9 ± 1.3	8.0 ± 0.8	14.0 ± 1.2	37.4 ± 2.1
8	6.7 ± 2.1	3.8 ± 0.8	9.1 ± 1.5	33.0 ± 2.3	7.7 ± 2.0	4.1 ± 0.4	9.3 ± 0.9	3.0 ± 1.8
10	3.7 ± 0.4	2.8 ± 0.2	8.0 ± 2.2	21.5 ± 0.1	3.9 ± 0.7	4.3 ± 0.4	8.4 ± 0.9	21.7 ± 1.4
12	3.8 ± 0.5	1.2 ± 0.2	6.8 ± 0.6	14.5 ± 1.5	3.3 ± 0.4	2.7 ± 0.7	6.9 ± 1.2	10.3 ± 0.7
Average	17.6 b	13.6 a	20.8 c	35.9 d	18.2 b	14.7 a	20.9 c	35.5 d
Significance	**	**	**	**	**	**	**	**

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): ** for 1%. For comparing the averages: impact of storage time (column); different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

The harvest of fruits of both cultivars was carried out with a low SSC of 6.1–6.4° Brix for 'Geneva' and for 'Ananasnaya', 8.6–6.8° Brix. The SSC increased in proportion to the loss of FF during storage (Table 2). Similarly, in this indicator, a drastic increase in value was noted during the first 2 weeks of storage in fruits of 'Geneva', regardless of the concentrations of O_2 and CO_2 in the cooling chamber. The increase in the SSC was slightly slower in the fruit of 'Ananasnaya', although even here, after 4 weeks, similar levels of SSC were observed as in the case of 'Geneva'. The process of SSC increase was slower in conditions of higher CO_2 concentration, i.e., in the CA2 combination. The analysis of the results showed that the composition of the atmosphere with a high CO_2 content favored a slightly slower increase in SSC values, but super-low oxygen conditions (DCA technology) also slightly slowed this process. The highest rate of increase in the SSC was observed during 8–10 weeks of storage in the ULO technology, after which a decrease in the SSC in the fruit was found in the following weeks of storage.

Table 2. Changes in total soluble solids content (° Brix) measured in 'Geneva' and 'Ananasnaya' minikiwi fruit in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	**ULO**	**CA1**	**CA2**	**DCA**	**ULO**	**CA1**	**CA2**
	Geneva							
0	6.4 ± 0.2				6.2 ± 0.3			
2	12.2 ± 0.8	11.9 ± 0.6	12.3 ± 0.7	10.1 ± 0.6	11.9 ± 0.6	11.2 ± 0.4	11.7 ± 0.7	10.5 ± 0.2
4	14.0 ± 1.4	14.8 ± 0.7	13.6 ± 0.6	12.3 ± 0.5	13.4 ± 1.2	14.0 ± 0.6	13.2 ± 0.5	12.8 ± 0.4
6	15.2 ± 0.5	17.6 ± 0.5	14.7 ± 0.3	12.1 ± 0.2	14.7 ± 0.2	16.2 ± 0.4	14.0 ± 0.1	12.7 ± 0.1
8	18.1 ± 0.5	17.2 ± 0.2	15.1 ± 0.5	14.2 ± 0.2	16.5 ± 0.3	15.6 ± 0.3	14.8 ± 0.4	14.5 ± 0.1
10	17.2 ± 0.1	16.2 ± 0.1	16.2 ± 0.1	14.1 ± 0.2	16.2 ± 0.2	15.6 ± 0.1	15.6 ± 0.1	14.8 ± 0.1
12	15.4 ± 0.6	15.8 ± 0.6	16.1 ± 0.5	14.8 ± 0.6	15.6 ± 0.4	15.6 ± 0.4	15.9 ± 0.4	15.7 ± 0.5
Average	14.1 bc	14.3 c	13.5 b	12.0 a	13.5 c	13.5 c	13.1 b	12.4 a
Significance	*	*	*	ns	*	*	*	ns

Table 2. *Cont.*

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Ananasnaya							
0	6.8 ± 0.2				6.7 ± 0.1			
2	9.8 ± 0.8	11.7 ± 0.8	10.9 ± 0.5	9.3 ± 0.5	8.9 ± 0.8	10.9 ± 0.5	9.23 ± 0.3	8.6 ± 0.6
4	12.3 ± 0.4	15.0 ± 0.7	13.0 ± 0.4	10.8 ± 0.7	11.1 ± 0.1	13.9 ± 0.3	11.8 ± 0.7	10.1 ± 0.4
6	14.2 ± 0.5	16.8 ± 0.3	14.4 ± 0.3	12.7 ± 0.3	13.1 ± 0.4	15.0 ± 0.1	13.4 ± 0.4	11.3 ± 0.4
8	15.0 ± 0.1	17.5 ± 0.5	14.6 ± 0.5	13.6 ± 0.4	13.4 ± 0.3	15.2 ± 0.4	13.7 ± 0.2	12.6 ± 0.2
10	14.8 ± 0.2	16.8 ± 0.3	15.6 ± 0.4	13.8 ± 0.3	4.0 ± 0.3	15.4 ± 0.4	14.3 ± 0.3	12.7 ± 0.3
12	15.4 ± 0.2	13.6 ± 0.4	15.4 ± 0.2	13.3 ± 0.4	14.8 ± 0.2	14.5 ± 0.2	14.6 ± 0.1	12.9 ± 0.6
Average	12.6 b	14.0 c	12.9 b	11.5 a	11.7 b	13.1 c	11.9 b	10.7 a
Significance	*	*	ns	ns	*	*	*	ns

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): * for 5%. For comparing the averages: impact of storage time (column); ns, lack of statistical significance; different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Similarly to the increase in the SSC in the fruit, a decrease in the sucrose content was observed (Table 3). An intense decrease in the content of this disaccharide was found in both years of research and in both cultivars after 2 weeks of storage. In the following weeks, the decomposition of sucrose into glucose and fructose was much slower, and in the fruit stored in conditions with a high CO_2 content (CA1 and CA2), it was at the border of statistical significance. The sucrose degradation was faster in the berries stored in DCA and ULO. However, there was no significant difference between DCA and CA1 in 2018 (6.52 and 6.85, respectively). An interesting fact is that 'Ananasnaya' fruit is characterized by a lower sucrose content than 'Geneva', but a quite similar content of sugars. As expected, the content of glucose and fructose increased during the storage of the fruit (Tables 4 and 5). In this case, such a drastic increase in the content of monosaccharides was not observed during the first weeks of storage, but the increase was statistically proven. The increase in the value of the indices took place at subsequent analysis dates, but it was clearly faster in the fruit stored in ULO and slower in the fruit stored in CA2, regardless of the year and variety. Therefore, after 12 weeks, the fruit stored in ULO was often characterized by a higher glucose and fructose contents than the fruit stored in CA2.

Apart from the sugar content, the fruit flavor is distinguished by the acid content. Hardy kiwi fruits have high TA which, after harvesting, can even exceed 1.0% citric acid. In both years of research, both cultivars were characterized by high TA after harvest (Table 6). During fruit ripening in the cold store, a loss of acidity was observed, but it was dependent on the storage conditions and the variety. Overall, it can be concluded that storage in conditions with high CO_2 contents help to keep the acidity of the fruit at a high level. Especially in 'Ananasnaya', despite the decrease in the index value in fruits stored in CA1 and CA2 conditions, this process was not proven in any of the years of research. On the other hand, after storage in low-oxygen conditions (DCA and ULO), the TA of the 'Ananasnaya' fruit decreased significantly. Similar relationships were observed in both years of research in 'Geneva' fruit, but a significant reduction in TA was observed regardless of the O_2 and CO_2 content. Citric and malic acids are mainly responsible for the acidity of the fruits of minikiwi. The fruits of both varieties contained the most citric acid, whereas the content of malic acid was several times lower (Tables 7 and 8). The contents of acids in the fruit of both cultivars depended on the year of the research. 'Geneva' fruits were characterized by a higher content of citric acid in 2017 than in 2018, especially immediately after harvest. The higher content of acid in the fruit during harvest did not significantly affect its higher content after 12 weeks of storage. The content of malic acid was twice as high in 2017 than 2018 in 'Ananasnaya' fruit, whereas in 'Geneva' fruit, no difference was observed between years. The composition of the atmosphere determined the rate of reduction in both acids. The concentration of CO_2 at the level of 10% contributed to maintenance of the contents of citric and malic acid in 'Ananasnaya' fruit at a statistically unchanged level in both years of study. Similar relationships were observed in 'Geneva', but not as effective at inhibiting acid loss. On the other hand, fruits stored in ULO conditions were characterized by a dynamic loss of both discussed acids during storage.

Table 3. Changes in sucrose contents (g·100 g^{-1} F.W.) measured in 'Geneva' and 'Ananasnaya' minikiwi fruits in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Geneva							
0	8.4 ± 0.4				8.00 ± 0.4			
2	6.05 ± 0.1	5.43 ± 0.3	6.28 ± 0.7	6.86 ± 0.1	6.81 ± 0.2	6.12 ± 0.3	7.00 ± 0.5	7.16 ± 0.1
4	6.49 ± 0.4	5.83 ± 0.3	7.10 ± 0.5	7.40 ± 0.3	6.57 ± 0.3	6.29 ± 0.2	7.02 ± 0.3	7.16 ± 0.3
6	5.80 ± 0.2	4.51 ± 0.3	6.15 ± 0.1	7.30 ± 0.4	6.28 ± 0.3	5.56 ± 0.2	6.41 ± 0.1	7.10 ± 0.3
8	7.00 ± 0.2	6.44 ± 0.4	7.60 ± 0.1	7.20 ± 0.6	6.32 ± 0.2	5.86 ± 0.2	6.76 ± 0.2	6.84 ± 0.1
10	6.69 ± 0.2	5.73 ± 0.3	7.50 ± 0.2	7.60 ± 0.3	5.97 ± 0.2	5.22 ± 0.1	6.51 ± 0.2	6.80 ± 0.2
12	6.68 ± 0.4	4.97 ± 0.3	6.99 ± 0.3	7.80 ± 0.1	5.69 ± 0.2	4.73 ± 0.2	6.03 ± 0.3	6.72 ± 0.1
Average	6.74 b	5.90 a	7.10 c	7.50 d	6.52 b	5.97 a	6.85 b	7.10 c
Significance	ns	*	*	ns	*	*	*	ns
	Ananasnaya							
0	6.7 ± 0.1				6.6 ± 0.1			
2	5.00 ± 0.2	4.25 ± 0.3	4.95 ± 0.4	5.87 ± 0.2	5.73 ± 0.1	5.00 ± 0.2	5.70 ± 0.3	6.28 ± 0.1
4	4.93 ± 0.3	4.11 ± 0.2	5.45 ± 0.3	5.47 ± 0.1	5.57 ± 0.2	5.00 ± 0.1	5.95 ± 0.2	5.88 ± 0.1
6	3.95 ± 0.2	3.60 ± 0.4	4.45 ± 0.2	5.37 ± 0.2	4.89 ± 0.1	4.24 ± 0.1	5.24 ± 0.2	5.81 ± 0.2
8	3.93 ± 0.3	3.49 ± 0.3	5.41 ± 0.4	6.31 ± 0.4	4.70 ± 0.2	4.29 ± 0.1	5.55 ± 0.3	6.07 ± 0.2
10	3.88 ± 0.1	3.25 ± 0.1	4.86 ± 0.1	6.21 ± 0.2	4.46 ± 0.1	4.05 ± 0.1	5.21 ± 0.1	5.89 ± 0.1
12	4.05 ± 0.3	2.70 ± 0.3	4.43 ± 0.3	5.71 ± 0.4	4.36 ± 0.2	3.57 ± 0.2	4.95 ± 0.2	5.47 ± 0.2
Average	4.63 b	4.01 a	5.17 c	5.94 d	5.19 b	4.68 a	5.61 c	6.00 d
Significance	*	*	*	*	**	**	*	*

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): * for 5%. ** for 1%. For comparing the averages: impact of storage time (column); ns, lack of statistical significance; different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Mass loss is an important indicator of the consumer quality of fruit, describing its drying up. Data analysis showed that both cultivars of fruits were characterized by a fairly similar rate of mass loss during storage (Table 9). However, after 12 weeks of storage, the 'Geneva' fruit exhibited a higher mass loss than the fruit of 'Ananasnaya'. The discussed index was determined by the conditions in which the fruit was stored. In both years of research, it was found that high concentrations of carbon dioxide at levels of 5% and 10% inhibited fruit mass loss during storage. Fruits stored in the CA1 and CA2 conditions after 12 weeks lost 42% and 54% less weight, respectively, than the fruit stored in an ultra-low oxygen (ULO) technology environment. The rate of mass loss of fruit stored in DCA and ULO was much faster in the initial storage period; a slowdown was observed after 8 weeks of storage. Despite quite significant mass loss, reaching the value of 3–4% after 12 weeks of storage, no signs of drying such as shrinkage or wrinkling of the skin were observed on the fruit.

Table 4. Changes in glucose contents (g·100 g^{-1} F.W.) measured in 'Geneva' and 'Ananasnaya' minikiwi fruits in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Geneva							
0	1.91 ± 0.04				2.03 ± 0.08			
2	2.41 ± 0.04	2.43 ± 0.07	2.38 ± 0.05	2.19 ± 0.02	2.25 ± 0.10	2.31 ± 0.03	0.22 ± 0.01	2.09 ± 0.04
4	2.66 ± 0.10	2.86 ± 0.16	2.66 ± 0.09	2.46 ± 0.08	2.55 ± 0.05	2.73 ± 0.19	2.50 ± 0.10	2.32 ± 0.07
6	3.04 ± 0.02	3.28 ± 0.04	2.91 ± 0.06	2.64 ± 0.07	2.90 ± 0.08	3.11 ± 0.06	2.76 ± 0.12	2.60 ± 0.13
8	3.63 ± 0.02	3.74 ± 0.02	3.39 ± 0.03	3.03 ± 0.04	3.55 ± 0.02	3.69 ± 0.05	3.37 ± 0.08	3.01 ± 0.10
10	3.47 ± 0.01	3.61 ± 0.02	3.55 ± 0.02	3.18 ± 0.08	3.46 ± 0.10	3.74 ± 0.12	3.46 ± 0.05	3.10 ± 0.05
12	3.24 ± 0.03	3.55 ± 0.05	3.61 ± 0.06	3.36 ± 0.08	3.55 ± 0.04	3.89 ± 0.03	3.67 ± 0.07	3.31 ± 0.04
Average	2.91 b	3.05 c	2.91 b	2.68 a	2.90 b	3.07 c	2.85 b	2.64 a
Significance	**	**	**	**	**	**	**	**
	Ananasnaya							
0	1.55 ± 0.04				1.51 ± 0.03			
2	1.78 ± 0.07	1.97 ± 0.06	1.83 ± 0.05	1.72 ± 0.05	1.68 ± 0.05	1.79 ± 0.04	1.68 ± 0.05	1.62 ± 0.05
4	2.04 ± 0.04	2.35 ± 0.08	2.11 ± 0.05	1.89 ± 0.06	1.86 ± 0.08	2.12 ± 0.10	1.94 ± 0.03	1.77 ± 0.05
6	2.42 ± 0.02	2.67 ± 0.04	2.37 ± 0.03	2.22 ± 0.05	2.26 ± 0.02	2.44 ± 0.06	2.16 ± 0.04	2.06 ± 0.06
8	2.83 ± 0.04	2.74 ± 0.04	2.84 ± 0.05	2.49 ± 0.03	2.72 ± 0.02	2.84 ± 0.03	2.78 ± 0.06	2.42 ± 0.02
10	2.75 ± 0.03	2.68 ± 0.03	3.01 ± 0.01	2.72 ± 0.07	2.69 ± 0.02	2.85 ± 0.04	2.82 ± 0.05	2.50 ± 0.05
12	2.75 ± 0.01	2.49 ± 0.02	3.08 ± 0.01	2.90 ± 0.07	2.84 ± 0.05	2.91 ± 0.06	3.03 ± 0.06	2.70 ± 0.04
Average	2.31 b	2.35 c	2.40 d	2.21 a	2.22 b	2.35 d	2.28 c	2.08 a
Significance	**	**	**	**	**	**	**	**

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): ** for 1%. For comparing the averages: impact of storage time (column); different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Minikiwi fruits selected for the tests were characterized by an intensely green color of the skin immediately after harvesting. However, during storage, the basic color of the rind changes, which was more pronounced in 'Geneva' fruits. Analysis of the results showed that the fruits stored in DCA and ULO technology lost their green color faster during storage (Table 10). A similar trend in the loss of chlorophyll pigments was observed in both cultivars in both years of study. High concentrations of carbon dioxide in the cooling chamber (CA1 and CA2 conditions) effectively inhibited the progressive decomposition of chlorophyll; unfortunately, it had an adverse effect on color saturation. Chroma index describing color saturation was much lower in fruit stored in technologies with a high content of carbon dioxide, which caused the skin to become dull (Table 11). The value of peel color saturation decreased with increasing carbon dioxide concentration in the chamber. Similar relationships were observed in both cultivars when analyzing the brightness (index L) of the fruit peel (Table 12). Additionally, in this case, the increasing concentration of carbon dioxide caused a decrease in the value of the L index, which substantiates the darkening of the skin color.

Table 5. Changes in fructose contents (g·100 g^{-1} F.W.) measured in 'Geneva' and 'Ananasnaya' minikiwi fruits in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Geneva							
0	2.30 ± 0.03				2.53 ± 0.04			
2	2.74 ± 0.07	2.65 ± 0.06	2.77 ± 0.04	2.63 ± 0.08	2.97 ± 0.05	2.90 ± 0.04	2.97 ± 0.04	2.82 ± 0.06
4	2.92 ± 0.16	2.99 ± 0.07	2.87 ± 0.02	2.84 ± 0.06	3.21 ± 0.14	3.31 ± 0.11	3.15 ± 0.04	3.08 ± 0.07
6	3.11 ± 0.09	3.38 ± 0.09	3.06 ± 0.02	2.92 ± 0.08	3.47 ± 0.10	3.76 ± 0.09	3.38 ± 0.05	3.22 ± 0.08
8	3.56 ± 0.07	3.94 ± 0.09	3.50 ± 0.03	3.21 ± 0.07	4.03 ± 0.06	4.40 ± 0.09	3.93 ± 0.03	3.58 ± 0.06
10	3.59 ± 0.05	3.94 ± 0.07	3.57 ± 0.04	3.27 ± 0.04	4.03 ± 0.07	4.42 ± 0.09	4.02 ± 0.04	3.66 ± 0.05
12	3.62 ± 0.06	4.17 ± 0.06	3.70 ± 0.07	3.44 ± 0.04	4.08 ± 0.07	4.65 ± 0.05	4.18 ± 0.07	3.86 ± 0.05
Average	3.12 b	3.34 c	3.11 b	2.94 a	3.47 b	3.71 c	3.45 b	3.25 a
Significance	**	**	**	**	**	**	**	**
	Ananasnaya							
0	2.19 ± 0.07				1.98 ± 0.05			
2	2.56 ± 0.09	2.66 ± 0.07	2.67 ± 0.01	2.55 ± 0.08	2.28 ± 0.07	2.27 ± 0.05	2.29 ± 0.04	2.28 ± 0.05
4	2.89 ± 0.05	3.16 ± 0.10	2.88 ± 0.05	2.71 ± 0.05	2.50 ± 0.07	2.66 ± 0.06	2.45 ± 0.07	2.36 ± 0.04
6	3.17 ± 0.05	3.53 ± 0.03	3.13 ± 0.07	2.99 ± 0.04	2.71 ± 0.06	2.98 ± 0.05	2.66 ± 0.08	2.58 ± 0.03
8	3.63 ± 0.07	3.53 ± 0.04	3.66 ± 0.06	3.29 ± 0.11	3.17 ± 0.10	3.36 ± 0.05	3.22 ± 0.10	2.86 ± 0.09
10	3.50 ± 0.06	3.47 ± 0.03	3.93 ± 0.05	3.38 ± 0.06	3.16 ± 0.03	3.31 ± 0.05	3.33 ± 0.05	2.98 ± 0.04
12	3.42 ± 0.03	3.17 ± 0.02	4.13 ± 0.06	3.48 ± 0.06	3.22 ± 0.04	3.33 ± 0.06	3.55 ± 0.05	3.07 ± 0.04
Average	3.05 b	3.10 b	3.23 c	2.94 a	2.72 b	2.84 d	2.78 c	2.59 a
Significance	**	**	**	**	*	**	**	ns

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): * for 5%. ** for 1%. For comparing the averages: impact of storage time (column); ns, lack of statistical significance; different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Table 6. Changes in titratable acidity (% citric acid) measured in 'Geneva' and 'Ananasnaya' minikiwi fruits in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Geneva							
0	1.17 ± 0.01				0.97 ± 0.09			
2	1.06 ± 0.06	0.98 ± 0.08	1.03 ± 0.03	1.01 ± 0.02	0.85 ± 0.08	0.77 ± 0.05	0.89 ± 0.09	0.82 ± 0.09
4	0.89 ± 0.02	0.86 ± 0.05	0.98 ± 0.04	0.97 ± 0.03	0.77 ± 0.07	0.68 ± 0.1	0.82 ± 0.04	0.81 ± 0.02
6	0.84 ± 0.01	0.81 ± 0.06	0.82 ± 0.07	0.89 ± 0.04	0.71 ± 0.06	0.74 ± 0.08	0.79 ± 0.12	0.77 ± 0.14
8	0.76 ± 0.03	0.74 ± 0.01	0.82 ± 0.05	0.78 ± 0.02	0.70 ± 0.12	0.61 ± 0.02	0.72 ± 0.01	0.67 ± 0.04
10	0.65 ± 0.02	0.64 ± 0.03	0.74 ± 0.02	0.72 ± 0.04	0.56 ± 0.01	0.49 ± 0.09	0.73 ± 0.02	0.74 ± 0.09
12	0.55 ± 0.04	0.52 ± 0.05	0.72 ± 0.04	0.72 ± 0.02	0.49 ± 0.06	0.41 ± 0.05	0.67 ± 0.05	0.65 ± 0.02

Table 6. *Cont.*

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	**ULO**	**CA1**	**CA2**	**DCA**	**ULO**	**CA1**	**CA2**
Average	0.85 a	0.82 a	0.90 b	0.89 b	0.72 ab	0.67 a	0.80 b	0.78 b
Significance	**	**	*	*	*	*	ns	ns
	Ananasnaya							
0	0.98 ± 0.13				0.97 ± 0.05			
2	0.78 ± 0.11	0.84 ± 0.04	0.88 ± 0.08	0.76 ± 0.13	0.81 ± 0.07	0.91 ± 0.03	0.90 ± 0.07	0.84 ± 0.08
4	0.76 ± 0.04	0.77 ± 0.05	0.82 ± 0.12	0.80 ± 0.02	0.83 ± 0.02	0.80 ± 0.06	0.88 ± 0.08	0.81 ± 0.02
6	0.67 ± 0.03	0.78 ± 0.13	0.90 ± 0.14	0.87 ± 0.19	0.75 ± 0.04	0.78 ± 0.08	0.96 ± 0.07	0.90 ± 0.12
8	0.76 ± 0.11	0.59 ± 0.08	0.79 ± 0.11	0.80 ± 0.12	0.79 ± 0.09	0.60 ± 0.02	0.83 ± 0.05	0.79 ± 0.06
10	0.65 ± 0.15	0.49 ± 0.03	0.79 ± 0.11	0.83 ± 0.09	0.66 ± 0.08	0.55 ± 0.05	0.82 ± 0.05	0.84 ± 0.05
12	0.50 ± 0.02	0.39 ± 0.10	0.71 ± 0.05	0.84 ± 0.08	0.60 ± 0.02	0.50 ± 0.04	0.78 ± 0.05	0.82 ± 0.06
Average	0.73 a	0.69 a	0.84 b	0.84 b	0.77 a	0.73 a	0.88 b	0.85 b
Significance	ns	*	ns	ns	*	*	ns	ns

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): * for 5%. ** for 1%. For comparing the averages: impact of storage time (column); ns, lack of statistical significance; different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Table 7. Changes in citric acid contents (g·100 g^{-1} F.W.) measured in 'Geneva' and 'Ananasnaya' minikiwi fruit in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	**ULO**	**CA1**	**CA2**	**DCA**	**ULO**	**CA1**	**CA2**
	Geneva							
0	1.15 ± 0.01				0.87 ± 0.09			
2	0.94 ± 0.04	0.85 ± 0.04	0.97 ± 0.01	0.94 ± 0.02	0.80 ± 0.16	0.76 ± 0.02	0.80 ± 0.09	0.81 ± 0.07
4	0.95 ± 0.02	0.82 ± 0.02	0.89 ± 0.03	0.93 ± 0.02	0.73 ± 0.09	0.70 ± 0.09	0.79 ± 0.05	0.76 ± 0.04
6	0.79 ± 0.01	0.80 ± 0.03	0.78 ± 0.05	0.97 ± 0.01	0.69 ± 0.09	0.68 ± 0.08	0.72 ± 0.10	0.72 ± 0.10
8	0.74 ± 0.02	0.77 ± 0.02	0.85 ± 0.02	0.87 ± 0.02	0.66 ± 0.05	0.61 ± 0.05	0.69 ± 0.02	0.69 ± 0.03
10	0.74 ± 0.01	0.59 ± 0.03	0.85 ± 0.02	0.87 ± 0.02	0.60 ± 0.02	0.58 ± 0.07	0.66 ± 0.04	0.67 ± 0.06
12	0.63 ± 0.02	0.63 ± 0.02	0.73 ± 0.02	0.71 ± 0.02	0.53 ± 0.06	0.52 ± 0.09	0.65 ± 0.06	0.63 ± 0.03
Average	0.85 ab	0.80 a	0.89 ab	0.92 b	0.70 a	0.67 a	0.74 b	0.74 b
Significance	*	*	*	*	**	**	*	*
	Ananasnaya							
0	0.74 ± 0.05				0.88 ± 0.02			
2	0.63 ± 0.03	0.68 ± 0.04	0.66 ± 0.01	0.64 ± 0.01	0.76 ± 0.02	0.78 ± 0.05	0.81 ± 0.05	0.74 ± 0.04
4	0.67 ± 0.01	0.59 ± 0.02	0.68 ± 0.01	0.66 ± 0.01	0.73 ± 0.01	0.71 ± 0.05	0.78 ± 0.03	0.77 ± 0.02
6	0.57 ± 0.03	0.56 ± 0.05	0.66 ± 0.01	0.63 ± 0.01	0.67 ± 0.02	0.64 ± 0.02	0.79 ± 0.04	0.77 ± 0.06
8	0.55 ± 0.06	0.50 ± 0.04	0.61 ± 0.01	0.61 ± 0.01	0.69 ± 0.03	0.57 ± 0.02	0.72 ± 0.04	0.74 ± 0.06
10	0.54 ± 0.07	0.44 ± 0.01	0.58 ± 0.01	0.60 ± 0.01	0.64 ± 0.04	0.48 ± 0.01	0.73 ± 0.05	0.73 ± 0.04
12	0.49 ± 0.02	0.33 ± 0.07	0.55 ± 0.01	0.59 ± 0.01	0.54 ± 0.02	0.42 ± 0.04	0.69 ± 0.01	0.74 ± 0.03

Table 7. *Cont.*

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
Average	0.60 b	0.55 a	0.64 c	0.64 c	0.70 b	0.64 a	0.77 c	0.77 c
Significance	*	**	*	ns	*	**	*	ns

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): * for 5%. ** for 1%. For comparing the averages: impact of storage time (column); ns, lack of statistical significance; different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Table 8. Changes in malic acid content (g·100 g^{-1} F.W.) measured in 'Geneva' and 'Ananasnaya' minikiwi fruits in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Geneva							
0	0.150 ± 0.014				0.130 ± 0.005			
2	0.144 ± 0.012	0.125 ± 0.014	0.142 ± 0.010	0.140 ± 0.015	0.137 ± 0.002	0.129 ± 0.003	0.136 ± 0.013	0.137 ± 0.007
4	0.124 ± 0.018	0.107 ± 0.003	0.126 ± 0.005	0.127 ± 0.010	0.117 ± 0.010	0.102 ± 0.008	0.120 ± 0.013	0.131 ± 0.012
6	0.112 ± 0.004	0.113 ± 0.018	0.129 ± 0.019	0.132 ± 0.019	0.114 ± 0.002	0.103 ± 0.005	0.124 ± 0.006	0.112 ± 0.005
8	0.107 ± 0.011	0.108 ± 0.002	0.118 ± 0.006	0.105 ± 0.010	0.109 ± 0.006	0.103 ± 0.006	0.110 ± 0.009	0.108 ± 0.009
10	0.093 ± 0.004	0.088 ± 0.011	0.121 ± 0.008	0.115 ± 0.008	0.097 ± 0.016	0.081 ± 0.014	0.109 ± 0.014	0.111 ± 0.005
12	0.083 ± 0.012	0.081 ± 0.007	0.106 ± 0.010	0.110 ± 0.004	0.077 ± 0.007	0.059 ± 0.005	0.104 ± 0.013	0.102 ± 0.013
Average	0.116 ab	0.110 a	0.127 b	0.126 b	0.111 b	0.101 a	0.119 b	0.119 b
Significance	*	*	ns	ns	*	*	*	*
	Ananasnaya							
0	0.216 ± 0.024				0.127 ± 0.006			
2	0.208 ± 0.001	0.204 ± 0.017	0.212 ± 0.008	0.218 ± 0.010	0.110 ± 0.007	0.109 ± 0.007	0.112 ± 0.004	0.112 ± 0.004
4	0.188 ± 0.023	0.188 ± 0.017	0.283 ± 0.012	0.180 ± 0.029	0.117 ± 0.003	0.103 ± 0.008	0.124 ± 0.006	0.103 ± 0.001
6	0.180 ± 0.018	0.150 ± 0.013	0.260 ± 0.005	0.218 ± 0.017	0.104 ± 0.006	0.085 ± 0.006	0.131 ± 0.006	0.114 ± 0.005
8	0.140 ± 0.013	0.137 ± 0.028	0.174 ± 0.006	0.177 ± 0.022	0.083 ± 0.003	0.072 ± 0.004	0.096 ± 0.004	0.102 ± 0.002
10	0.169 ± 0.017	0.134 ± 0.016	0.201 ± 0.018	0.194 ± 0.012	0.081 ± 0.008	0.060 ± 0.003	0.097 ± 0.006	0.100 ± 0.005
12	0.140 ± 0.009	0.105 ± 0.009	0.183 ± 0.027	0.185 ± 0.024	0.075 ± 0.007	0.056 ± 0.009	0.096 ± 0.008	0.103 ± 0.003
Average	0.177 ab	0.162 a	0.212 b	0.198 b	0.099 b	0.087 a	0.112 c	0.109 c
Significance	*	*	*	ns	*	*	*	*

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): * for 5%. For comparing the averages: impact of storage time (column); ns, lack of statistical significance; different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Table 9. Changes in fruit mass loss (%) measured in 'Geneva' and 'Ananasnaya' minikiwi fruits in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Geneva							
2	0.48 ± 0.06	0.87 ± 0.07	0.59 ± 0.32	0.35 ± 0.13	0.76 ± 0.08	0.89 ± 0.05	0.43 ± 0.12	0.22 ± 0.07
4	1.27 ± 0.10	1.45 ± 0.37	1.12 ± 0.27	0.49 ± 0.02	1.48 ± 0.06	1.91 ± 0.12	0.84 ± 0.11	0.39 ± 0.06

Table 9. *Cont.*

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
6	2.07 ± 0.19	2.83 ± 0.08	1.59 ± 0.27	1.02 ± 0.11	1.90 ± 0.13	2.59 ± 0.09	1.18 ± 0.10	0.86 ± 0.10
8	2.95 ± 0.42	3.22 ± 0.45	2.02 ± 0.32	1.39 ± 0.17	2.66 ± 0.40	3.31 ± 0.20	1.77 ± 0.14	1.16 ± 0.08
10	3.15 ± 0.23	3.75 ± 0.13	2.25 ± 0.25	2.21 ± 0.20	3.09 ± 0.06	3.98 ± 0.14	2.12 ± 0.19	1.71 ± 0.16
12	3.90 ± 0.46	4.72 ± 0.25	2.82 ± 0.61	2.59 ± 0.26	3.66 ± 0.20	4.51 ± 0.26	2.61 ± 0.35	2.05 ± 0.17
Average	2.30 b	2.81 b	1.73 ab	1.34 a	2.26 b	2.86 b	1.49 a	1.06 a
Significance	**	**	**	**	**	**	**	**
	Ananasnaya							
2	0.38 ± 0.08	0.52 ± 0.14	0.22 ± 0.09	0.36 ± 0.11	0.46 ± 0.06	0.48 ± 0.08	0.33 ± 0.05	0.51 ± 0.11
4	0.90 ± 0.08	1.45 ± 0.09	0.33 ± 0.09	0.53 ± 0.13	1.11 ± 0.09	1.40 ± 0.07	0.62 ± 0.02	0.71 ± 0.09
6	1.87 ± 0.03	2.61 ± 0.13	0.92 ± 0.11	0.92 ± 0.07	1.94 ± 0.14	2.37 ± 0.07	1.28 ± 0.06	1.29 ± 0.04
8	2.80 ± 0.06	2.83 ± 0.02	1.22 ± 0.15	1.07 ± 0.16	2.52 ± 0.04	2.84 ± 0.13	1.70 ± 0.12	1.52 ± 0.10
10	3.08 ± 0.18	3.14 ± 0.06	1.84 ± 0.12	1.41 ± 0.11	3.02 ± 0.15	3.25 ± 0.31	1.91 ± 0.08	1.82 ± 0.09
12	3.44 ± 0.19	3.77 ± 0.07	2.23 ± 0.44	1.74 ± 0.25	3.24 ± 0.15	3.51 ± 0.09	2.30 ± 0.13	2.08 ± 0.13
Average	2.08 b	2.39 b	1.13 a	1.01 a	2.14 b	2.31 b	1.36 a	1.32 a
Significance	**	**	**	**	**	**	**	**

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): ** for 1%. For comparing the averages: impact of storage time (column); ns, lack of statistical significance; different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Table 10. Changes in skin color (parameter 'L') measured in 'Geneva' and 'Ananasnaya' minikiwi fruits in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Geneva							
0	58.4 ± 0.87				55.5 ± 0.69			
2	58.8 ± 1.14	58.5 ± 0.28	58.2 ± 0.73	57.3 ± 0.23	53.2 ± 1.61	55.0 ± 2.20	53.2 ± 1.33	52.2 ± 0.57
4	59.2 ± 0.50	58.3 ± 1.06	59.0 ± 0.48	58.1 ± 0.23	55.6 ± 0.31	53.9 ± 0.94	51.5 ± 0.52	54.3 ± 0.69
6	58.7 ± 0.39	56.4 ± 0.91	56.7 ± 0.31	54.6 ± 0.52	53.6 ± 1.47	53.4 ± 1.13	51.4 ± 1.43	50.4 ± 0.68
8	54.6 ± 1.54	53.8 ± 0.38	52.2 ± 1.93	53.3 ± 0.25	51.2 ± 2.05	49.2 ± 1.64	47.3 ± 1.75	51.0 ± 0.12
10	56.1 ± 0.39	53.8 ± 0.14	53.1 ± 0.22	52.6 ± 0.11	51.4 ± 1.27	50.0 ± 1.45	49.0 ± 0.40	49.3 ± 0.70
12	55.3 ± 0.37	52.7 ± 0.46	51.9 ± 0.41	51.4 ± 0.26	51.4 ± 1.47	48.7 ± 1.71	46.8 ± 1.04	47.5 ± 1.24
Average	57.3 c	56.0 b	55.6 ab	55.1 a	53.1 b	52.2 ab	51.1 a	51.5 a
Significance	*	*	*	*	ns	*	*	*
	Ananasnaya							
0	55.6 ± 0.90				56.0 ± 0.79			
2	56.0 ± 0.73	55.8 ± 1.37	54.7 ± 0.47	54.9 ± 0.47	56.4 ± 0.60	56.2 ± 1.33	55.3 ± 0.58	55.3 ± 0.49
4	54.1 ± 1.05	53.4 ± 0.95	52.9 ± 0.44	52.2 ± 1.03	54.7 ± 0.98	53.8 ± 1.06	53.4 ± 0.30	52.9 ± 0.99
6	55.6 ± 0.19	53.8 ± 0.67	53.6 ± 0.87	52.4 ± 0.42	56.0 ± 0.22	54.4 ± 0.67	54.0 ± 0.70	52.9 ± 0.48
8	54.0 ± 0.21	51.4 ± 0.64	51.8 ± 0.69	51.1 ± 0.24	54.6 ± 0.24	51.9 ± 0.70	52.3 ± 0.61	51.6 ± 0.18

Table 10. *Cont.*

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
10	54.4 ± 0.19	51.1 ± 0.31	51.1 ± 0.40	50.0 ± 0.33	54.8 ± 0.14	51.6 ± 0.31	51.7 ± 0.35	50.5 ± 0.36
12	53.9 ± 0.15	50.2 ± 0.26	50.4 ± 0.17	48.9 ± 0.25	54.4 ± 0.13	50.7 ± 0.28	50.8 ± 0.17	49.4 ± 0.25
Average	54.8 c	53.0 b	52.8 b	52.2 a	55.3 c	53.5 b	53.4 b	52.7 a
Significance	*	*	*	*	*	*	*	*

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): * for 5%. For comparing the averages: impact of storage time (column); ns, lack of statistical significance; different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Table 11. Changes in skin color (Chroma) measured in 'Geneva' and 'Ananasnaya' minikiwi fruits in the postharvest period.

Time of Storage (Weeks)	2017				2018			
	Storage Conditions							
	DCA	ULO	CA1	CA2	DCA	ULO	CA1	CA2
	Geneva							
0	23.5 ± 0.92				23.5 ± 0.71			
2	23.8 ± 0.72	22.8 ± 0.05	23.5 ± 0.24	23.7 ± 0.68	23.9 ± 0.61	22.7 ± 0.15	23.4 ± 0.46	23.7 ± 0.73
4	20.8 ± 0.51	20.9 ± 0.83	22.1 ± 0.32	18.4 ± 0.13	20.6 ± 0.56	20.9 ± 1.05	22.0 ± 0.29	18.4 ± 0.41
6	19.0 ± 0.59	17.4 ± 1.03	19.4 ± 0.37	17.3 ± 0.37	18.7 ± 0.74	17.6 ± 1.17	19.4 ± 0.50	17.3 ± 0.34
8	15.7 ± 1.05	15.2 ± 0.51	15.3 ± 0.42	14.6 ± 0.99	15.7 ± 1.06	15.0 ± 0.58	15.0 ± 0.47	14.4 ± 1.27
10	15.5 ± 0.71	14.7 ± 0.33	14.7 ± 0.75	13.4 ± 0.46	14.5 ± 0.82	14.0 ± 0.57	14.3 ± 0.72	12.6 ± 0.56
12	13.6 ± 0.62	13.5 ± 0.47	13.0 ± 0.32	12.3 ± 0.56	13.1 ± 0.77	12.3 ± 0.75	12.7 ± 0.61	11.5 ± 0.49
Average	18.8 b	18.3 b	18.8 b	17.6 a	18.6 b	18.0 b	18.6 b	17.2 a
Significance	**	**	**	**	**	**	**	**
	Ananasnaya							
0	25.7 ± 1.18				26.2 ± 1.17			
2	23.6 ± 0.78	23.3 ± 0.88	23.2 ± 0.41	22.7 ± 1.03	22.3 ± 0.22	23.5 ± 0.77	22.9 ± 1.00	22.9 ± 1.40
4	24.4 ± 0.38	22.8 ± 0.85	22.8 ± 0.37	21.5 ± 0.55	23.8 ± 1.20	22.5 ± 1.43	22.3 ± 0.64	21.4 ± 1.03
6	21.5 ± 0.40	20.2 ± 0.20	19.5 ± 0.54	18.9 ± 0.47	21.3 ± 0.66	14.4 ± 0.53	19.6 ± 0.65	18.6 ± 1.08
8	19.4 ± 0.43	17.1 ± 0.27	16.6 ± 0.47	16.2 ± 0.89	20.3 ± 1.01	16.7 ± 0.44	17.0 ± 0.86	16.3 ± 0.82
10	18.8 ± 0.61	17.0 ± 0.53	16.2 ± 0.56	15.1 ± 0.42	18.7 ± 0.95	16.0 ± 0.34	16.1 ± 1.00	14.5 ± 0.73
12	17.2 ± 0.25	16.1 ± 0.36	15.3 ± 0.65	13.5 ± 0.12	17.5 ± 0.37	15.4 ± 0.52	14.87 ± 1.29	12.5 ± 0.96
Average	21.5 c	20.3 b	19.9 b	19.1 a	21.4 b	19.2 a	19.8 ab	18.9 a
Significance	**	**	**	**	*	*	*	*

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): * for 5%. ** for 1%. For comparing the averages: impact of storage time (column); different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

Table 12. Changes in skin color (Hue Angle) measured in 'Geneva' and 'Ananasnaya' minikiwi fruits in the postharvest period.

Time of Storage (Weeks)	**2017**				**2018**			
	Storage Conditions							
	DCA	**ULO**	**CA1**	**CA2**	**DCA**	**ULO**	**CA1**	**CA2**
	Geneva							
0	118.3 ± 0.1				118.8 ± 0.1			
2	117.7 ± 0.2	118.8 ± 0.1	118.8 ± 0.1	117.7 ± 0.1	117.7 ± 0.1	117.7 ± 0.1	117.7 ± 0.1	117.7 ± 0.1
4	117.7 ± 0.1	117.7 ± 0.1	117.7 ± 0.1	117.7 ± 0.1	118.8 ± 0.1	118.8 ± 0.1	118.8 ± 0.1	118.8 ± 0.3
6	116.6 ± 0.1	115.5 ± 0.3	116.6 ± 0.1	115.5 ± 0.2	117.7 ± 0.2	116.6 ± 0.7	117.7 ± 0.1	117.7 ± 0.2
8	113.3 ± 1.8	105.6 ± 5.0	108.9 ± 3.1	114.4 ± 0.2	110.0 ± 3.4	108.9 ± 5.1	114.4 ± 1.7	116.6 ± 0.4
10	111.1 ± 0.6	103.4 ± 2.5	108.9 ± 1.1	112.2 ± 0.3	111.1 ± 1.1	107.8 ± 2.6	113.3 ± 1.0	114.4 ± 0.6
12	108.9 ± 0.9	99.0 ± 1.8	104.5 ± 1.4	108.9 ± 1.0	108.13 ± 1.1	103.1 ± 2.1	111.1 ± 0.2	112.2 ± 0.5
Average	114.2 c	110.0 a	112.6 b	114.4 c	113.9 ab	112.1 a	115.5 b	116.2 b
Significance	**	**	**	**	**	**	**	**
	Ananasnaya							
0	107.3 ± 0.3				106.4 ± 0.2			
2	108.0 ± 0.1	107.7 ± 0.1	107.7 ± 0.1	107.7 ± 0.1	105.2 ± 0.3	105.8 ± 0.3	105.7 ± 0.3	106.0 ± 0.3
4	107.3 ± 0.3	107.3 ± 0.5	107.7 ± 0.1	108.0 ± 0.1	104.0 ± 0.6	104.2 ± 0.7	105.0 ± 0.5	105.7 ± 0.1
6	106.7 ± 0.4	106.3 ± 0.7	107.0 ± 0.2	107.0 ± 0.1	103.2 ± 0.3	102.9 ± 0.7	103.4 ± 0.4	104.2 ± 0.4
8	105.3 ± 0.3	105.0 ± 0.7	106.0 ± 0.4	106.7 ± 0.3	101.6 ± 0.4	101.4 ± 0.8	102.3 ± 0.4	103.0 ± 0.1
10	104.3 ± 0.7	103.7 ± 0.4	105.3 ± 0.2	106.3 ± 0.6	100.0 ± 0.4	99.8 ± 0.6	101.2 ± 0.5	102.6 ± 0.6
12	102.0 ± 0.8	101.0 ± 0.8	104.0 ± 0.8	105.0 ± 0.1	98.2 ± 0.9	98.1 ± 0.6	99.9 ± 0.8	101.1 ± 0.5
Average	105.9 a	105.5 a	106.4 b	106.9 b	102.0 a	102.0 a	102.9 b	103.7 c
Significance	*	**	*	*	**	**	*	*

DCA, dynamic controlled atmosphere, 0.4% CO_2:0.4% O_2; ULO, ultra-low oxygen, 1.5% CO_2:1.5% O_2; CA1, controlled atmosphere, 5% CO_2:1.5% O_2; CA2, controlled atmosphere, 10% CO_2:1.5% O_2; ±, standard deviation; statistically significant difference (Newman–Keuls range test): * for 5%. ** for 1%. For comparing the averages: impact of storage time (column); different letters are assigned to statistically significant differences when comparing storage conditions (average for time of storage).

4. Discussion

In recent years, the commercial cultivation of fruit species previously considered as amateur ones has been developing dynamically in Europe. This is due to the "Eco" trend among consumers who are looking for new fruit with an interesting taste, but with functional food features, i.e., increased pro-health values, such as antioxidants or fiber. Minikiwi fits perfectly into this trend because its fruits contain very large amounts of C vitamin [12] and carotenoids [34], and they can also be used for their anti-cancer properties and in other diets [35]. A weakness of minikiwi is its poor storage capability compared to kiwi fruit, but similar to other berries, such as highbush blueberries [11,12].

The development of an appropriate minikiwi fruit storage procedure that allows for the long-term storage and long-distance transport of the fruit has been the goal of many research studies in recent years [11,25,27]. The main problem is maintaining the proper FF. Some studies [14,20,25] emphasize that minikiwi loses its firmness during 1–2 weeks of storage in low-temperature conditions. Storing the fruit in a controlled atmosphere will extend this period to a maximum of 6–8 weeks [11]. In our own experiment, the influence of different O_2 and CO_2 concentrations on FF during storage was assessed. It turned out that the low-oxygen conditions are not conducive to inhibiting the softening process of the minikiwi, as is the case with pome fruit. However, it turned out to be beneficial to increase the CO_2 content in the environment of the fruit, because even after 12 weeks of storage in CO_2 at a concentration of 10%, the berries did not soften enough to be fit for consumption. This proves a stronger influence of CO_2 on ethylene synthesis, which causes the activation of exo-polygalacturonase and other enzymes, contributing to the softening of minikiwi [18,21]. Some authors point out that the loss of firmness in the fruits of kiwi is not only caused by ethylene, because its softening takes place at very low levels (i.e., 0.005–0.01 mL L1) [18,36]. There is also a hypothesis that low temperatures may induce softening and increase ethylene sensitivity, as is the case in kiwi fruit (*Actinidia chinensis* Planch.) [37]. The results of our own research seem to confirm these reports, because CO_2 is a well-known inhibitor of ethylene production, and its high concentration effectively blocked the minikiwi softening process at low temperatures.

The process of fruit ripening is not only softening, and ethylene is responsible for other physiological aging processes of the fruit. During the growth of the minikiwi on the shrub, the total contents of sugars and starch increased in order to decrease during ripening [13,38]. Starch is degraded during fruit storage. The changes take place under the influence of enzymes such as α-amylase, ß-amylase, α-glucosidase, and starch phosphorylase. As a result of these transformations, oligosaccharides, maltose, glucose, or phosphate-1-glucose are formed. The results of our own research indicate a fast growth rate of SSC, whereas the increases in glucose and fructose content were slower. In the experiment, a drastic increase in SSC was observed during the first 2 weeks of storage. Additionally, Park et al. [39] observed an increase in extract content during the storage of *A. deliciosa* fruits. The results obtained by Strik [30] show that the SSC in *A. arguta* fruits can reach values of up to 25° Brix, but neither in these studies nor in the work of Fisk et al. [14] were high values of SSC achieved. The SSC is associated with the products of starch degradation (poli- and monosacharaides) [40] and organic acids, amino acids, and other soluble substances. The consumption of monosacharaides in the respiration process and the decomposition of sucrose can be determined by the concentration of gases in the cooling chamber. It turns out that a drastic reduction in O_2 to a level of 0.4% in the atmosphere slows down respiration and, at the same time, the consumption of monosacharaides, hence the observed increase in their content. It is worth noting, however, that after 8 weeks of storage, a different trend was noted and the glucose and fructose contents in fruit stored, especially in ULO, started to decrease slightly or remained unchanged. This probably indicates a faster respiration rate of the fruit stored in this way, as a similar effect was not observed in the combinations of CA1 and CA2. Therefore, it can be concluded that the minikiwi respiration process is equally effective, if not more effective, in blocking storage in high CO_2 concentrations, because the content of both monosaccharides for 12 weeks increased in the fruit stored in these combinations, regardless of the cultivar.

The literature reports to date [14,25] indicate that during minikiwi maturation, the acidity decreases. This is due to the consumption of acids during the respiration process; therefore, limiting this process should inhibit the loss of acidity by the fruit. There are two basic acids in minikiwi: citric and malic. As expected, the acid content decreased during the 12 weeks of storage, but the process depended on the conditions in which the fruit was stored. Earlier reports [11,12] have indicated that modifications of the gas composition in the cooling chamber (1.5%:1.5%, CO_2:O_2) effectively reduce the loss of organic acids during storage compared to normal cooling conditions. The results of the experiment showed that at high CO_2 concentrations, the TA and the content of citric and malic acid remained stable, which was particularly evident in 'Ananasnaya'. Low-oxygen conditions (DCA) turned out to be slightly less effective. By analyzing the results of SSC, TA, and the content of simple sugars and acids, it can be concluded that CO_2 is a much more effective inhibitor of respiration processes, because the mentioned indicators are determined by fruit respiration.

The peel color change is caused by the degradation of chlorophyll as the fruits ripen. Both cultivars were characterized by an intensely green basic skin color, immediately after harvesting. During fruit ripening in the cold store, it was found, similarly to the previously discussed indicators, that the loss of green color progressed slightly faster under ULO and DCA conditions than CA1 and CA2. There is no information in the literature on changes in the skin color of minikiwi as a result of the interaction of variable compositions of O_2 and CO_2. In the research by Szpadzik [11], it was shown that the storage of the 'Ananasnaya' minikiwi in CA technology more effectively reduces the degradation of dyes responsible for the green color of the peel. Fisk et al. [14] proved that the harvest date is an important factor influencing color changes during minikiwi storage in refrigerated conditions. The results of our own research indicate that CO_2 contributes to the maintenance of the green color of the fruit, but the fruit is duller and darker than the fruit stored in ULO or DCA.

An important feature of the appearance of the fruit, apart from its color, is the structure of the skin. During storage, fruit loses its mass due to transpiration and respiration. Losing mass causes the fruit to wilt, which can be manifested by wrinkling of the skin. In the experiment, no such effects were found on the peel of the fruit, despite the relatively high mass loss. According to Fisk et al. [14] minikiwis can lose up to 3% of their weight during 8 weeks of refrigerated storage. Unfortunately, the authors did not conduct experiments in a controlled atmosphere. The results obtained in the experiment show that the storage conditions affect mass loss, which is caused by more intensive transpiration in the DCA or ULO technology, where the relative air humidity was slightly lower than in the CA1 and CA2 conditions. The difference in air humidity is related to the more frequent adjustments of the gas composition made by the CO_2 absorber and nitrogen generator. Lowering the relative air humidity by a few percentage points results in higher fruit mass loss, as reported by Szpadzik et al. [11]. The authors also emphasize that earlier fruit harvest with SSC 6.5° Brix may contribute to greater mass loss during storage, explained by a smaller wax layer covering the skin. Our own research showed significant varietal differences. 'Geneva', with an earlier fruit ripening time than 'Ananasnaya', showed almost a twofold lower mass loss than 'Ananasnaya', which may prove that the wax coverage of the skin is more strongly determined as a cultivar trait.

5. Conclusions

The aim of the experiment was to determine the effect of low O_2 concentrations and high CO_2 concentrations on the physicochemical parameters of hardy kiwi fruits. It was shown that the evaluated factors affected fruit quality. Minikiwis, similarly to other berries, do not have good storage capability. Research results indicate that the use of high concentrations of CO_2 (5–10%) effectively inhibits ripening processes in fruit. In ULO or DCA technology, the softening process lasts up to about 6–8 weeks of storage, but 10% CO_2 concentration prolongs this period twice. After 12 weeks of storage in CA2 (10% CO_2:1.5% O_2), fruits of both cultivars were not fit for consumption, which suggests that the storage period can be further extended. The content of other indices was more stable when fruits were stored in high CO_2 as opposed to in low O_2. The disadvantage of storing fruit in a high CO_2 atmosphere is dulling and darkening of the peel. The super-low O_2 concentration obtained in DCA is also quite effective in slowing down ripening processes, but due to the high cost of this technology and its lower efficiency, it is unlikely to find practical use in minikiwi storage.

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