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Effect of Controlled Atmosphere Storage Conditions on the Chemical Composition of Super Hardy Kiwifruit

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Abstract: Super hardy kiwifruit [*Actinidia kolomikta* (Maxim. & Rupr.) Maxim.] accumulate large amounts of biologically active compounds, but it is possible to store ripe fruit for a very short time, only 2 weeks at 0–5 °C. Therefore, it is necessary to determine optimal storage conditions to prolong fruit storage time. The aim of this research was to analyse changes in the basic chemical composition of fruit during ripening in controlled atmosphere chambers. Fruit was stored for 6 weeks at a constant temperature (0 °C) and humidity (90%) in different air compositions (No. 1—21% O_2, 78% N_2; No. 2—0.5% O_2, 98.5% N_2, 1% CO_2; No. 3—1.5% O_2, 95.5% N_2, 3% CO_2; No. 4—2% O_2, 93% N_2, 5% CO_2). The chemical composition of the fruit was determined at harvest, after 2, 4 and 6 weeks of storage. Dry matter, soluble solids, ascorbic acid, total chlorophyll and carotenoid contents were analysed. The greatest increase in the contents of dry matter and soluble solids after 6 weeks of storage was found in the chamber where O_2 was 2% and CO_2 was 5%. The ascorbic acid content decreased during the fruit ripening process regardless of the air composition. Most of the ascorbic acid remained in fruit stored in the chamber with 1.5% O_2 and 3% CO_2. The concentration of total chlorophyll and total carotenoids in the fruit increased as development progressed. The different air parameters in the storage chambers had different effects on the synthesis of pigments in fruit, but the content of pigments increased most in fruit stored in the chamber with atmospheric parameters 0.5% O_2 + 1% CO_2.

Keywords: *Actinidia kolomikta*; ascorbic acid; carotenoids; chlorophylls; controlled atmosphere

1. Introduction

Super hardy kiwifruit [*Actinidia kolomikta* (Maxim. & Rupr.) Maxim.] is the most resilient species in the genus *Actinidia*; this species is tolerant of temperatures as low as approximately −40 °C in winter, although it is susceptible to late spring frosts. The development of *Actinidia* as a commercial crop has potential for growth in northern regions, not only because of the plant's tolerance to cold, but also because of the high vitamin C content of the fruit [1–4]. *A. kolomikta* fruit accumulate large amounts of vitamin C, and for this reason could be one of a main sources of this vitamin in the Lithuanian's diet. The concentration of vitamin C in *A. kolomikta* fruit varies from 2423 to 11,460 mg kg^{-1}, depending on the cultivar and meteorological conditions [2,3]. Our previous studies have indicated that the greatest amounts of vitamin C are found in the unripe *A. kolomikta* fruit [2]. These data confirm the results of

other researchers; that the vitamin C content of many fruits is higher when they are slightly immature, and declines as the fruit reaches peak ripeness [5,6].

A. kolomikta fruit are distinguished by green peel and flesh colour, even at the consumption maturity stage, which is due to large amounts of chlorophyll. The basic pigments present in these fruits are chlorophylls and carotenoids [1]. In plants, chlorophyll is usually degraded during ripening. Mature green kiwifruit (*Actinidia chinensis* var. *deliciosa*) are an exception, with high concentrations of chlorophyll remaining in the fruit flesh [7]. According to researchers, amounts of carotenoids, such as vitamin C, are affected by environmental conditions [8]. Sunlight and higher ambient temperatures promote the biosynthesis of carotenoids, thereby increasing the carotenoid levels during maturation. Carotenoid levels continue to rise after harvest. In kiwifruit, carotenoids accumulated to a greater concentration during the fruit ripening process [8].

It is possible to store ripe *A. kolomikta* fruit for only 10–14 days at 0–5 °C. Storage time can be extended by creating optimal conditions. Fruit storage in a controlled atmosphere maintains fruit quality and flavour, reduces storage losses and extends shelf life [9,10]. Post-harvest compositional changes occur depending on the conditions and duration of storage. Based on previous research, kiwifruit have been classified as a climacteric fruit due to their high sensitivity to ethylene, which is the best-known plant hormone for its effect on fruit ripening [11]. The inhibition of the synthesis of ethylene is advantageous, which helps slow down the processes related to fruit ripening, i.e., softening, chlorophyll degradation and the breakdown of starch into simple sugars [9]. The biosynthesis and physiological function of ethylene depend on the O_2 concentration [12]. The minimum O_2 concentration typically used in controlled atmosphere storage is 2–5%, and depends on the kind of produce, the temperature, and the duration of storage [13]. The production of ethylene suppresses the high concentrations of CO_2. The respiration response to high levels of CO_2 depends upon the crop, cultivar and the stage of development, but in general, the exogenous ethylene and low O_2/high CO_2 concentrations act antagonistically [14]. Some researchers pointed out that high a CO_2 concentration in the storage atmosphere caused degradation of vitamin C in freshly cut kiwifruit slices [15]. The atmospheres commonly used for kiwifruit storage are 2% O_2 with 5% CO_2 or 2% O_2 with 2% CO_2, depending on the cultivars [14]. The relative humidity in most controlled atmosphere rooms used for kiwifruit is 90–94% [13,14].

This study aimed to evaluate the changes to the basic chemical composition of *Actinidia kolomikta* fruit during storage in controlled atmosphere chambers with different air parameters.

2. Materials and Methods

2.1. Plant Materials and Storage Conditions

Fruit of super hardy kiwi [*Actinidia kolomikta* (Maxim. & Rupr.) Maxim.] cultivars 'Laiba', 'Lankė', 'Landė' and 'Paukštės Šakarva' were obtained from the Vytautas Magnus University Agriculture Academy orchard (54°53′ N, 23°50′ E) in the central region of Lithuania. These cultivars were developed at the University orchard from selected seedlings, grown from free pollination seeds of 'Klara Cetkin' and 'Ananasnaja' cultivars in 1972, which have been under investigation since 1988. The fruit were handpicked at the beginning of August 2015 and 2016, 60–65 days after abundant flowering, when, according to recommendations, the soluble solids content was between 9.0% and 10.5%, depending on the cultivar [16]. Picked fruit were put into perforated boxes, and promptly transported to the laboratory. The fruit in the boxes, 4 × 10.0 kg for each cultivar, were placed in controlled atmosphere chambers (Besseling CA Systems, Besseling Group B.V., Oosterblokker, The Netherlands) and stored for 6 weeks at constant temperature (0 °C) and humidity (90%) in different air compositions [No. 1—21% oxygen (O_2), 78% N_2; No. 2—0.5% O_2, 98.5% N_2, 1% carbon dioxide (CO_2); No. 3—1.5% O_2, 95.5% N_2, 3% CO_2; No. 4—2% O_2, 93% N_2, 5% CO_2] until fully ripe. Required values of temperature, humidity and air composition were set up, measured, controlled and maintained automatically.

2.2. Chemical Analysis

The chemical composition of the fruit was determined at harvest (0 days) and after 2, 4 and 6 weeks of storage. Fruit were analysed immediately after removal from storage. For chemical analysis, 1 kg laboratory sample was made for each cultivar fruit. The whole fruit were homogenised with peels and seeds.

2.2.1. Determination of Dry Matter and Soluble Solids Content

Dry matter (DM) content was assessed by drying the samples to constant mass at 105 °C; soluble solids content (SSC) was measured by the refractometric method at 20 °C using a digital refractometer PAL-1 (Atago CO., Ltd., Tokyo, Japan) using fruit juice pressed from homogenised fruit.

2.2.2. Determination of Ascorbic Acid Content

Ascorbic acid (AA) was determined by titration with 2,6-dichlorphenol-indophenol sodium salt dehydrate [17].

2.2.3. Determination of Total Chlorophyll and Carotenoids Content

Total chlorophyll (TCh) and total carotenoid (TCar) contents were analysed using a two-ray UVS-2800 spectrophotometer (Labomed Inc., Los Angeles, CA, USA). The absorbance was read at 470, 645 and 662 nm and the amount of pigments was calculated as described by Straumite et al. [18]. For pigment extraction, 0.3 g of homogenised fruit was weighed in a conical flask, extracted with 50 mL 100% acetone and mixed using a magnetic stirrer (VWR International, Radnor, PA, USA) for 15 min at 700 rpm. The supernatant was then separated. The chemicals used in this study were of analytical grade. Chemical analyses were performed in three replications.

2.3. Statistical Analysis

Statistical analysis was carried out with software TIBCO Statistica, version 7 (TIBCO Software, Palo Alto, CA, USA). The arithmetical means and standard deviations (SD) of the experimental data were calculated. The research data were evaluated using analysis of variance (ANOVA) method. The significance of the differences between the cultivar and chemical composition were evaluated by the one-way ANOVA method. An interaction effect was checked using Fisher's least-significant-difference (LSD) test at the significance level of $p < 0.05$. Differences between cultivars (4 cultivars), storage time (2, 4 and 6 weeks) and chemical composition (DM, SSC, AA, TCh, TCar), as well as between air composition in chambers (4 variants), storage time and chemical composition, were analysed using factorial analysis of variance. A comparison of means was performed with Fisher's LSD test. Interaction between factors was determined and the *p*-value of criterion F which was less than 0.05 showed that the investigated factors had a statistically significant effect on the chemical composition of fruit. Linear correlation and regression analyses were performed to determine the strength and character of the relationships between variables at a probability level of 95%.

3. Results and Discussion

3.1. Chemical Composition of Actinidia Kolomikta Fruit at Harvest

The concentrations of micronutrients and bioactive compounds in plants at harvest are known to vary with variety or cultivar, stage of maturity, geographic or climatic effects, agricultural practices and soil composition [19]. In the case of *A. kolomikta* fruit, some of the biochemical compounds significantly depend on the cultivar [2]. Significant differences between cultivars were observed in the DM, AA, TCh and TCar contents. SSC of three cultivars varied slightly; only 'Paukštės Šakarva' fruit differed significantly ($p < 0.05$). The greatest amount of DM accumulated in 'Laiba', the greatest amounts of SSC and AA were observed in 'Landė' fruit, and the greatest amount of TCh was observed in 'Paukštės

Šakarva' fruit (Table 1). No significant differences in TCar content were established between 'Laiba' and 'Paukštės Šakarva' fruit. A greater amount of SSC indicates that 'Landė' fruit ripen earlier than other investigated cultivars, due to the faster hydrolysis of starch. These results are supported by our previous studies [3,20].

Table 1. Chemical composition of *Actinidia kolomikta* fruit at harvest.

Cultivar	Dry Matter %	Soluble Solids Content %	Ascorbic Acid mg kg^{-1}	Total Chlorophyll mg kg^{-1}	Total Carotenoid mg kg^{-1}
'Landė'	15.29 ± 0.72 b *	10.02 ± 0.34 a	5632.76 ± 199.13 a	6.50 ± 0.11 d	1.47 ± 0.05 c
'Lankė'	15.21 ± 0.62 b	9.77 ± 0.34 a	4442.79 ± 160.95 c	11.28 ± 0.18 c	2.47 ± 0.02 b
'Laiba'	18.11 ± 0.54 a	9.93 ± 0.14 a	5090.69 ± 163.86 b	15.31 ± 0.07 b	5.31 ± 0.02 a
'Paukštės Šakarva'	13.14 ± 0.94 c	8.68 ± 0.35 b	5041.78 ± 182.77 b	24.89 ± 0.12 a	5.24 ± 0.06 a

* Significant differences ($p < 0.05$) in columns are marked by different letters; for each measured parameter general mean ± SD is presented.

3.2. Changes in Dry Matter and Soluble Solid Contents of Fruit During Storage

The DM content is used as an index of the quality and taste of the fruit. Researchers suggested that DM measurements made at any time after harvest of kiwifruit (*A. chinensis* var. *deliciosa*) provide a reliable predictor of the SSC of ripe fruit, and hence fruit quality [21]. This method is applicable for the determination of *A. kolomikta* fruit ripeness. Since the fruit of *A. kolomikta*, like *A. deliciosa*, are harvested unripe and left to ripen before consumption.

In this study, the DM content increased over the course of the ripening process in all cultivars of fruit (Table 2). The increase in DM content was on average 10% in 'Landė', 14% in 'Lankė', 20% in 'Laiba' and 14% in 'Paukštės Šakarva' fruit (Tables 1 and 2). After 6 weeks of storage, a significant increase in DM content developed in all cultivars except 'Lankė' fruit (Table 2). 'Laiba' fruit were distinguished significantly from all cultivars, with the highest content of DM.

Table 2. Dependence of the chemical composition of *Actinidia kolomikta* fruit on cultivar and storage time.

Cultivar	Storage Time Weeks	Dry Matter % (n = 20)	Soluble Solids Content % (n = 24)	Ascorbic Acid mg kg^{-1} (n = 24)	Total Chlorophyll mg kg^{-1} (n = 24)	Total Carotenoid mg kg^{-1} (n = 24)
'Landė'	2	15.78 ± 1.19 d	11.35 ± 0.22 i	5306.97 ± 548 a	17.94 ± 1.58 f,g	7.19 ± 0.69 f,g
	4	15.52 ± 1.20 d,e	12.56 ± 0.50 f	5238.15 ± 794 a	16.65 ± 0.75 g,e	8.36 ± 0.43 f
	6	16.88 ± 1.64 c	13.44 ± 0.75 d	3888.97 ± 1014 e	28.18 ± 0.44 b,c,d	12.23 ± 0.35 d,e
'Lankė'	2	15.99 ± 0.83 d	11.70 ± 0.41 h	4646.72 ± 305 b	41.37 ± 3.12 a	16.47 ± 1.08 b
	4	16.88 ± 0.86 c	12.85 ± 0.30 e	4420.05 ± 661 c	29.81 ± 1.42 b,c	13.53 ± 0.77 c,d
	6	17.34 ± 1.50 c	13.76 ± 0.91 c	3708.12 ± 212 f,g	26.02 ± 0.31 d,e	12.28 ± 0.20 d,e
'Laiba'	2	18.81 ± 1.01 b	12.83 ± 0.40 e	4211.35 ± 813 d	20.49 ± 0.72 f	7.40 ± 0.25 f
	4	19.21 ± 1.65 b	14.91 ± 0.38 b	4456.36 ± 1062 c	31.22 ± 1.00 b	14.42 ± 0.52 c
	6	21.77 ± 1.89 a	15.38 ± 2.54 a	3584.06 ± 562 g	40.06 ± 1.08 a	19.68 ± 0.58 a
'Paukštės Šakarva'	2	14.14 ± 0.60 f	10.23 ± 0.39 j	5250.36 ± 614 a	12.87 ± 0.57 h	5.66 ± 0.31 g
	4	13.99 ± 1.35 f	11.38 ± 0.21 i	4698.89 ± 483 b	26.48 ± 1.36 c,d,e	12.80 ± 0.65 c,d,e
	6	14.93 ± 1.51 e	12.03 ± 0.71 g	3860.28 ± 155 e,f	24.38 ± 0.99 e	11.31 ± 0.44 e

Calculations between cultivars × storage time × chemical composition parameters were performed. Data presented as an average of all storage air compositions. For each measured parameter general mean ± standard deviation is presented; within each parameter values with different letters differ significantly according to the LSD (Fisher's least-significant-difference) test, when $p < 0.05$.

Chambers with 1.5% O_2 + 3% CO_2 (chamber No. 3) and 2% O_2 + 5% CO_2 (chamber No. 4) presented a significant increase in DM content in fruit (Table 3). The largest average increase (32%) in DM content of all the investigated cultivars was found in chamber (No. 4) with 2% O_2 + 5% CO_2. After 6 weeks of storage, the smallest average content of DM was found in fruit stored in chamber (No. 1), with the highest O_2 content (21%).

Table 3. Dependence of the chemical composition of *Actinidia kolomikta* fruit on controlled atmosphere parameters and storage time.

Chamber No.	Storage Time Weeks	Dry Matter % (n = 20)	Soluble Solids Content % (n = 24)	Ascorbic Acid mg kg^{-1} (n = 24)	Total Chlorophyll mg kg^{-1} (n = 24)	Total Carotenoid mg kg^{-1} (n = 24)
1	2	16.00 ± 1.82 f,g,h	11.24 ± 1.15 j	4364.93 ± 322 d,e	33.03 ± 3.74 a	12.75 ± 1.36 b,c
	4	16.40 ± 2.47 g,e,f	12.88 ± 1.36 e	5379.16 ± 572 a	24.75 ± 1.27 d,e	11.95 ± 0.64 c
	6	16.81 ± 3.63 c,d,e	13.04 ± 1.57 d	3771.06 ± 219 f	27.17 ± 1.47 b,c,d	13.68 ± 0.80 a,b
2	2	16.20 ± 1.93 g,e,f	11.59 ± 0.79 i	5276.31 ± 531 a	14.12 ± 0.82 f	5.40 ± 0.19 f
	4	17.21 ± 2.22 b,c,d	13.16 ± 1.51 c	4485.36 ± 569 c,d	24.13 ± 1.06 d,e	11.56 ± 0.51 c,d
	6	17.32 ± 2.43 b,c	12.37 ± 0.80 g	3151.66 ± 503 g	32.78 ± 1.19 a	14.14 ± 0.68 a,b
3	2	15.89 ± 1.83 g,h	11.55 ± 0.92 i	4843.29 ± 1021 b	23.73 ± 0.86 d,e	10.25 ± 0.39 d
	4	15.45 ± 2.02 h	12.95 ± 1.14 d,e	4555.66 ± 454 c	25.54 ± 1.45 c,d	11.13 ± 0.75 c,d
	6	17.55 ± 2.17 b	14.20 ± 1.56 b	4223.99 ± 573 e	29.66 ± 0.44 a,b	13.96 ± 0.22 a,b
4	2	16.64 ± 2.15 d,e,f	11.72 ± 1.09 h	4930.88 ± 644 b	21.80 ± 0.83 e	8.32 ± 0.47 e
	4	16.55 ± 2.32 e,f	12.71 ± 1.31 f	4393.26 ± 1170 d	29.74 ± 1.32 a,b	14.48 ± 0.64 a
	6	19.24 ± 3.14 a	15.01 ± 2.09 a	3894.72 ± 467 f	29.01 ± 0.29 b,c	13.73 ± 0.14 a,b

Calculations between chambers × storage time × chemical composition parameters were performed. Data presented as an average of all storage air compositions (1—21% O_2, 78% N_2; 2—0.5% O_2, 98.5% N_2, 1% CO_2; 3—1.5% O_2, 95.5% N_2, 3% CO_2; 4—2% O_2, 93% N_2, 5% CO_2). For each measured parameter general mean ± standard deviation is presented; within each parameter values with different letters differ significantly according to the LSD (Fisher's least-significant-difference) test, when $p < 0.05$.

The DM content and SSC are closely related [14]. The relationship between DM and SSC is only reliable after fruit ripening is complete [21]. Statistical analysis of our data shows that, for fruit at harvest, the DM is poorly correlated with SSC ($r = 0.30$, $R^2 = 0.09$, $p < 0.05$). However, for ripe fruit, the correlation is much stronger, and after 4 weeks of storage the correlation coefficient r ranged from 0.60 to 0.72 ($R^2 = 0.36$–0.52, $p < 0.05$). Researchers assert that such changes are expected, given that approximately 80% of the kiwifruit dry matter is carbohydrates; when fruit are unripe, that is sugar and starch, and mostly sugar when fully ripe [21]. This statement also applies to describing changes in *A. kolomikta* fruit, even for the fruit being stored under different air parameters.

The SSC, like the DM content, increased in fruit during post-harvest maturation. The significant increase in SSC was observed in the fruit of all the cultivars stored for 6 weeks in a controlled atmosphere, and reached on average 34% in 'Landė', 41% in 'Lankė', 55% in 'Laiba', and 39% in 'Paukštės Šakarva' fruit (Tables 1 and 2). Starch hydrolysis in kiwifruit (*A. deliciosa* 'Hayward'), as implied by a decrease in the starch concentration and a corresponding increase in that of soluble solids, begins prior to harvest. However, the most rapid breakdown of starch occurs during the first few weeks of storage [22]. The greatest increase in SSC in *A. kolomikta* fruit of approximately 20% was observed after 2 weeks of storage (Table 2).

Kiwifruit research demonstrated that, while SSC increases with ripening, it may increase or decrease during storage as carbohydrates are utilised in fruit respiration [23]. The same changes were observed when *A. kolomikta* fruit were stored in controlled atmosphere chambers. After 4 weeks, the SSC increased by an average of 12% in all chambers compared to the SSC after 2 weeks of storage; after 6 weeks, the SSC increased only 6% compared to the SSC after 4 weeks of storage (Table 3). The overall SSC increased by 42% compared to the SSC of fruit at harvest. All chambers presented a significant increase in SSC in fruit after 6 weeks of storage. An atmosphere with 2% O_2 + 5% CO_2 at 0 °C (chamber No. 4) led to the greatest increase in the SSC and DM content in fruit of all cultivars. A low O_2 and CO_2 atmosphere (chamber No. 2) caused the smallest increase in DM and SSC in the fruit. The interaction between cultivars' DM, SSC and chambers were not significant for all cultivars studied.

3.3. Changes in Ascorbic Acid Content of Fruit during Storage

The content of AA in fruit and vegetables can be influenced by various factors, such as genotypic differences, pre-harvest climatic conditions and cultural practices, maturity and harvesting methods, and post-harvest handling procedures. The higher the intensity of light during the growing season, the greater the AA content is in plant tissues [24]. Studies of kiwifruit genetic factors indicated that the accumulation of AA showed a relatively high heritability [25]. The researchers found that the level of

GDP-L-galactose phosphorylase in various genotypes of kiwifruit correlated with AA content during fruit development [25]. Meanwhile, the content of AA depends on the clones, and decreases during storage [26].

In this study, the greatest amount of AA at harvest [5632.76 mg kg^{-1} of fresh weight (FW)] and after 6 weeks of storage (3888.97 mg kg^{-1} of FW) were observed in 'Landė' fruit. Our previous studies indicate that fruit of this cultivar usually accumulates larger amounts of AA [2].

According to research, the harvest time of kiwifruit significantly influenced the AA concentration [27]. All of the investigated *A. kolomikta* cultivars were of similar maturity. Nevertheless, during storage in the controlled atmosphere chambers, the amount of AA in the fruit varied depending on the cultivar (Table 2). In blackcurrants, AA accumulated early in fruit development during the expansion stage [19]. In kiwifruit, the rates of both AA biosynthesis and degradation varied with fruit maturity [26]. The results obtained with blackcurrant fruit were similar those for the *A. kolomikta* fruit. In our study, the highest content of AA was observed in *A. kolomikta* fruit at harvest, and it decreased significantly in all cultivars during the fruit ripening process. The AA content decreased an average of 4% after 2 weeks of storage, 7% after 4 weeks of storage, and 26% after 6 weeks of storage, compared to fruit at harvest (Tables 1 and 2). After 6 weeks of storage, the highest content of AA was found in 'Landė' and 'Paukštės Šakarva' fruit. In particular, loss of fresh weight (water loss) during storage of kiwifruit can also accelerate AA degradation [28].

If fruit and vegetables are maintained in their optimum atmospheres, the retention of AA and other vitamins results in a better nutritional quality [29]. Our research has shown that the air composition in the chambers differently influenced the amount of AA in the stored fruit. On average, most of the AA remained after storage in an atmosphere with 1.5% O_2 and 3% CO_2 (chamber No. 3) (Table 3). Degradation of AA was faster in the low O_2 and CO_2 atmosphere (chamber No. 2), particularly after 6 weeks of storage. All chambers presented a significant decrease in AA content in fruit within 6 storage weeks. The lowest AA content after 6 weeks was found in fruit stored in an atmosphere with 0.5% O_2 + 1% CO_2 (chamber No. 2). The interaction between cultivars and chambers was not significant for the AA content of fruit.

3.4. Changes in Pigments Content of Fruit during Storage

Depending on the species and cultivar, *Actinidia* fruit also contain substantial amounts of various pigments, including carotenoids, chlorophylls and anthocyanins [30]. In our study, the amounts of TCh and TCar in the fruit of various cultivars of *A. kolomikta* at harvest differed significantly, from 6.50 to 24.89 mg kg^{-1} FW of TCh, and from 1.47 to 5.31 mg kg^{-1} FW of TCar (Table 1). According to other researchers, the kiwiberry contains between 2.6 and 4.2 mg 100 g^{-1} FW of chlorophyll [1,30]. Differences in pigment composition suggest a significant influence of climatic and genetic factors on these compounds [31,32].

Our research has shown that the concentration of TCh and TCar in the fruit increased as development progressed during storage. The TCh and TCar contents in *A. kolomikta* fruit after 6 weeks of storage were several times higher than in the fruit at harvest. After 6 weeks of storage, the TCh content was higher by, on average, 2-fold, and the TCar content was higher by, on average, 4-fold, compared to the fruit at harvest (Tables 1 and 2). An optimum atmosphere inhibits the loss of chlorophyll and the biosynthesis of carotenoids [29]. The findings of these researchers are confirmed by our results. During storage in different controlled atmospheres, the content of pigments in various cultivars of *A. kolomikta* fruit changed unequally, but the interaction between cultivars and chambers was not significant. The greatest amounts of pigments were observed in 'Lankė' fruit after 2 weeks, and in 'Laiba' fruit after 4 and 6 weeks of storage (Table 2). After 6 weeks of storage, a significant increase in pigments content was fixed in all the cultivars' fruit except 'Paukštės Šakarva'.

All chambers presented a significant increase in pigment content in fruit at the end of storage, except the chamber with 2% O_2 + 5% CO_2 (chamber No. 4) (Table 3). The data show that the greatest amounts of pigments in fruit after 6 weeks were found in an atmosphere with 0.5% O_2 + 1% CO_2

and 1.5% O_2 + 3% CO_2 (chamber No. 2 and No. 3). During storage, the average content of pigments increased most in fruit stored in an atmosphere with 0.5% O_2 + 1% CO_2 (chamber No. 2) and least in an atmosphere with 21% O_2 (chamber No. 1), compared to fruit at harvest.

4. Conclusions

The chemical composition of *Actinidia kolomikta* fruit at harvest varied depending on the cultivar. The dry matter and soluble solids contents in fruit increased after harvest. Storage in an atmosphere containing 2% oxygen (O_2) and 5% carbon dioxide (CO_2) at 0 °C led to the greatest increase in the soluble solids content and dry matter content after 6 weeks of storage in fruit of all cultivars. The most ascorbic acid content was observed in *A. kolomikta* fruit at harvest, and ascorbic acid content decreased during the fruit ripening process regardless of the air composition in the storage chambers. On average, most of the ascorbic acid content remained after storage in an atmosphere with 1.5% O_2 + 3% CO_2. The concentration of total chlorophyll and total carotenoid in the fruit increased as maturity progressed. The different air parameters in the storage chambers had different effects on the synthesis of pigments in fruit, but the content of pigments increased most in fruit stored in the chamber with atmospheric parameters 0.5% O_2 + 1% CO_2.

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