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Influence of cold storage on fruit quality of some kiwifruit genotypes organically produced

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RAMONA CRISTINA COTRUȚ*, FLORIN STĂNICĂ, SORIN MIHAI CÎMPEANU
University of Agronomic Sciences and Veterinary Medicine 59, Blvd. Mărăşti, 011464, Bucharest, Romania
** **Address correspondence to:** University of Agronomic Sciences and Veterinary Medicine 59, Blvd. Mărăşti, 011464, Bucharest, Romania.*
Tel: +4021 318 36 36; e-mail: ramona.cotrut@gmail.com

Abstract

The research focused on the effects of cold storage on postharvest quality of four kiwifruit genotypes grown in organic conditions. The changes of physicochemical and mechanical properties for harvested kiwifruit were obtained according to the measurements applied before and during storage period. The fruit quality attributes of three Actinidia deliciosa hybrid selections (R1P17, R1P18 and R1P19) and one interspecific hybrid (A. deliciosa x A. chinensis), R1P2 were determined at harvest, after 4 and respectively, 9 weeks of cold storage in normal atmosphere. Soluble solids content (SSC) and pH increased as fruit firmness and titratable acidity (TA) decreased during the storage. Based on fruit firmness results, smaller sized interspecific hybrid fruits (A. deliciosa x A. chinensis) appear to have lower storage life potential than A. deliciosa hybrid selections. R1P17 had higher soluble solids (SSC %) and dry matter (DM %) content. The longest storage life was in R1P17 with the best quality attributes. No storage diseases were observed during the storage period.

Keywords: *Actinidia deliciosa, A. deliciosa x A. chinensis*, Brix, flesh firmness, storage life.

1. Introduction

Kiwifruit is recognized as highly nutritious and low calories fruit with the potential to deliver a range of health benefits (DRUMMOND [1]). There are many researches focused on the *Actinidia deliciosa* cultivar *Hayward* (green kiwifruit) concerning its health benefits, good storage life and possibilities of maintaining and controlling postharvest kiwifruit ripening (BURDON & al. [2]; STONEHOUSE & al. [3]). The long fruit storage life has high economic importance, making possible the marketing of the fruits much later after their harvest season. The fruit quality is given by different parameters which express a complete picture of the fruit characteristics. The optimum kiwifruit storage temperature to slow down the process of ripening is at 0°C (LALLU & al. [4]). The kiwifruit has a storage life of three to six months, which is one of its more valuable attributes (NISHIYAMA [5]). There have been researches that show a potential link between storage life and size of kiwifruit, as well as sugar development and fruit size. Within the same genotype, the percentage of dry matter (DM) was reduced in larger fruit compared to smaller fruit of *A. deliciosa* (NARDOZZA & al. [6]; NARDOZZA & al. [7]). The maturity level, colors, sugar, solids, size and mechanical defect, firmness etc. are some of the important factors for kiwifruit marketing (CANGI & al. [8]). Recently, there have been other reported data regarding the changes in physicochemical parameters of kiwi fruits ripening during cold storage (FERGUSON [9]; FIORENTINO & al. [10]). The objectives of this research focused on monitoring the effects of kiwifruit genotype, size and quality on postharvest storage life. The changes of physicochemical and mechanical properties for harvested kiwifruit were obtained according to the measurements applied before and during storage period.

2. Material and methods

2.1. Kiwifruit samples

Within the Experimental Field of the Horticulture Faculty, University of Agronomic Sciences and Veterinary Medicine, Bucharest, three *Actinidia deliciosa* hybrid selections (R1P17, R1P18 and R1P19) and one interspecific hybrid (*A. deliciosa x A. chinensis*), R1P2 from adult vines (Figure 1), were harvested at 24th of October 2014 from an organic orchard, (26°6'0" East longitude and 44°25'60"North latitude).

Figure 1. Studied kiwifruits genotypes: A - R1P17; B – R1P2; C – R1P19 and D – R1P18.

2.2. Harvesting and post-harvest storage of kiwifruit

Harvesting moment was established at the end of October, when the fruit soluble solids content was around 7° Brix. After harvesting, the kiwi fruits were kept in cold storage at T = 4±0.5 °C and RH > 90%, for 9 weeks.

2.3. Fruit flesh firmness

Fruit flesh firmness was determined by measuring penetration force using a penetrometer (Fruit Tester Wagner FDK Force Gage, FT10 10 lbf x 2 ozf 5 kgf x 50 gf FT 516) equipped with a cylinder of 8 mm diameter. Flesh firmness was measured and expressed in kg force per cm^2 of flesh.

2.4. Determination of soluble solids content (SSC), dry matter (DM), pH and total acidity (TA)

The soluble solids content (SSC - Brix), pH and total acidity (TA) were performed in clear juice obtained from homogenized and filtered peeled kiwi fruits. The SSC was measured using a handheld refract meter (Brix 35 HP Reichert Inc., USA). PH was determined using a pH-meter (Digital plant pH meter Puxicoo). The total acidity was measured in 4 ml of juice, diluted to 20 ml of distilled water and titrated with 0.1 N NaOH to a pH of 8.2. The TA was expressed as a percentage of malic acid per kg of fresh fruit. Fruit dry matter content was determined by drying the kiwi fruits at 105°C in a forced air oven to constant weight.

2.5. Sensorial analysis

Sensorial quality was carried out in a sensorial testing laboratory by different age ranging consumers. Fruit quality was evaluated by appearance and taste (sweetness, sourness, flavor, texture) and for the results it was used a 1–5 rating scale (1 = bad, 2 = moderate, 3 = good, 4 = very good, 5 = excellent).

2.6. Statistical analysis

Statistical evaluation of the experimental data was performed by simple comparisons of mean values performed by Student's t-test and level of significance was accepted at $p \leq 0.05$.

3. Results and discussion

During the post-harvest storage, the kiwifruits removed from the plant continued the physiological development until they become suitable for consumption. The size of green kiwifruits ranged from medium (77.71 g at R1P18) to large size (92.60 g at R1P17), while the yellowish fruit of the interspecific hybrid (R1P2) was rather small in size with only 30 g (Table 1). The values in this case for the harvested kiwifruit of our genotypes were higher of those reported in previous studies (YILDIRIM & al. [11]).

3.1. Flesh firmness

Flesh firmness loss is one of the main factors limiting quality and the postharvest shelf life of kiwifruit. The physicochemical properties of kiwifruit genotypes began to change during cold storage, starting with week 4. The flesh firmness (Kgf/cm^2) of R1P19 medium size kiwifruits changed from 5.26 ± 0.20 to 1.14 ± 0.13. The firmness of R1P17, large size kiwifruits, reduced from 5.54 ± 0.21 at harvesting time to 1.61 ± 0.11 at the end of storage, while for R1P2, small size kiwifruit, the flesh firmness reduced from 4.04 ± 0.28 to 0.74 ± 0.15 after 9 weeks of cold storage (Table 2). The life storage of kiwifruit was influenced by the degree of flesh softening; kiwifruits were ready to eat when the flesh firmness reached 0.74 ± 0.15. Our results show similarity with other results (Krupa & al. [12]), where firmness rapidly decreased and the SSC increased for all genotypes during the entire period of storage at 4°C.

Table 1. Fruit physical characteristics of studied genotypes at the harvesting moment (SM= Small, MD= Medium, LG= Large)

Genotypes	Fruit size	Fruit weight (g)	Fruit diameter (mm)	Fruit length (mm)
R1P2	SM	30.00	34.00	39.00
R1P17	LG	92.60	48.60	59.10
R1P18	MD	77.71	46.80	56.20
R1P19	MD	78.00	47.20	62.40

3.2. Determination of soluble solids content (SSC), dry matter (DM), pH and total acidity (TA)

The evolution of kiwifruits biochemical properties (SSC, dry matter, pH and TA) during storage for 0, 4 and 9 weeks, respectively, is presented in Table 2. SSC (°Brix) of R1P2 kiwifruits ranged from 6.25 ± 0.15 to 14.32 ± 0.24, while for R1P17, from 7.41 ± 0.24 to 16.33 ± 0.26. Our results confirm that cold storage at 4 ± 1°C and 90% RH is suitable for maintaining our kiwi fruit genotypes in high quality (ZOLFAGHARI & al. [13]). *Actinidia deliciosa* hybrid selections were comparable to the one grown in Italy (CASTALDO & al.

[14]). The physicochemical indices of "Hayward" grown in Italy results differ with our obtained data shown in Tables 2. Brix changed from 7.83 ± 0.06 to 14.97 ± 0.12 in comparison with ours of 7.41 ± 0.24 to 16.33 ± 0.26 during 9 weeks. PH changed from 3.58 ± 0.01 to 3.66 ± 0.02 in comparison with 3.10 ± 0.01 to 2.93 ± 0.02 for the same cultivar grown in Italy. SSC, dry matter and pH increased, while TA and flesh firmness decreased in kiwi fruits after 9 weeks of storage in a controlled atmosphere (4°C, 90% relative air moisture). During the 9 weeks of storage, pH value of all kiwi genotypes increased from the lowest value of 3.40 ± 0.02 to 3.60 ± 0.01 for R1P18, compared to the values of R1P17 which ranging from 3.58 ± 0.01 to 3.66 ± 0.02. TA (%) visibly decreased for all genotypes during storage period. For R1P18 kiwifruits, TA was reduced from 1.12 ± 0.01 to 0.85 ± 0.04 and for R1P17 from 1.48 ± 0.02 to 0.94 ± 0.05. The effect of storage on SSC, TA and dry matter for all kiwifruits genotypes was statistically significant ($p<0.05$). The sensorial appreciation value (score) for R1P2 varied from 1.15 ± 0.31 at the harvest moment, to 1.49 ± 0.44 after 4 weeks and to 1.71 ± 0.21 after 9 weeks of storage. R1P17 was appreciated in the range from 1.62 ± 0.33 at the harvest moment to 3.29 ± 0.29 after 4 weeks and to 4.43 ± 0.49 after 9 weeks of storage. The results showed that the kiwifruits stored for 9 weeks reached ripeness with an acceptable to excellent quality (Figure 2).

Table 2. Effects of cold storage on SSC, dry matter pH, TA and flesh firmness of kiwifruits genotypes

Genotypes	Time storage (weeks)	SSC (°Brix)	Dry matter (%)	pH	Acidity (%)	Firmness (kgf/cm^2)
R1P2	0	6.25±0.15	16.37±0.10	3.48±0.01	1.46±0.04	4.04±0.24
	4	9.72±0.17	16.23±0.11	3.56±0.02	1.12±0.01	2.28±0.17
	9	14.32±0.24	16.48±0.12	3.63±0.01	0.92±0.03	0.74±0.15
R1P17	0	7.41±0.24	16.48±0.14	3.58±0.01	1.48±0.02	5.54±0.21
	4	10.3±0.18	16.23±0.9	3.61±0.02	1.12±0.01	3.59±0.13
	9	16.33±0.26	16.71±0.10	3.66±0.02	0.94±0.05	1.61±0.11
R1P18	0	6.50±0.23	15.94±0.15	3.40±0.02	1.12±0.01	5.17±0.17
	4	9.16±0.13	16.15±0.08	3.51±0.03	0.94±0.02	3.17±0.25
	9	12.23±0.22	16.05±0.11	3.60±0.01	0.85±0.04	1.26±0.14
R1P19	0	6.29±0.19	15.87±0.13	3.45±0.01	1.47±0.01	5.26±0.20
	4	8.30±0.26	16.04±0.11	3.59±0.02	1.12±0.01	3.22±0.16
	9	11.24±0.20	15.95±0.12	3.62±0.01	0.91±0.05	1.14±0.13

Note: Values are means ± SD of 10 measurements; means within the columns are statistically significant ($p < 0.05$; Student's t-test).

Based on other studies regarding the evolution of physicochemical properties of cultivar Hayward during cold storage for 0, 4 and 18 weeks, the average fruit composition varied was as follows: starch = 0.3–7.0%, °Brix = 6.5–14.8% and acidity = 1.8–2.5% of the studied cultivars. Hayward had the best overall quality particularly with regard to its resistance to softening. Our results are in line according to previous findings with *A. deliciosa* 'Hayward', in which the larger sized fruit reportedly have greater potential for a long storage life (CRISOSTO & al. [15]). The influence of fruit size on fruit quality attributes and storage life was slightly variable. Flesh firmness is typically the primary indicator of storage life potential. Fruit size did not consistently affect flesh firmness for the entire duration of this study. However, there were several interactions of the main effects of storage duration and size in the latter weeks of cold storage in which the larger fruit were firmer than medium and smaller fruit for our *Actinidia deliciosa* hybrid selections that indicated that larger fruit have greater storage life potential.

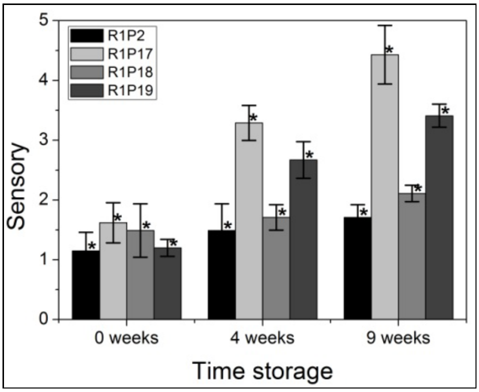

Figure 2. The sensorial appreciation value (score) for all genotypes during storage period.
Note: Values are means ± SD of 10 measurements; means within histogram, the columns with one * are considered to be statistically significant ($p < 0.05$; Student's t-test). 1–5 rating scale (1 = bad, 2 = moderate, 3 = good, 4 = very good, 5 = excellent).

4. Conclusions

Based on fruit firmness results, smaller sized *A. deliciosa* x *A. chinensis* fruits appear to have less cold storage life potential than the larger sized fruit cultivars. Firmness significantly decreased from harvesting and the storage starts in all kiwifruit genotypes from week 4 to week 9. At the end of storage stage, R1P2 had the lowest values in terms of firmness comparing with R1P17, R1P18 and R1P19. Soluble solids content increased with storage time, while acidity gradually decreased. The fruit quality attributes and storage life of R1P17 were comparable to R1P2. R1P17 fruits had higher soluble solids content (SSC) and percentage of dry matter (DM). After 9 weeks of storage, the flesh firmness decreased till the optimum eating quality. In general, this experiment showed that the longest storage life was in R1P17 with the BEST quality attributes. No storage diseases were observed during the storage period. Further studies are required to investigate antioxidant enzyme activity, antioxidant capacity and flavonoid concentrations.

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