INTERNAL QUALITY OF APPLES DURING STORAGE
ĀBOLU IEKŠĒJĀS STRUKTŪRAS KVALITĀTE GLABĀŠANAS LAIKĀ

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Kopsavilkums

Pētījumi veikti divas sezonas (2003./2004. un 2004./2005.) 29 ābolu šķirnēm no sešgadīgiem kokiem, kas potēti uz M.9. Āboli tika vākti, kad to cietes indekss bija no 6 līdz 8. Āboli glabāti 4 mēnešus +2°C temperatūrā. Ābolu mīkstuma blīvums, titrējamo skābju saturs, šķīstošā sausna tika noteikti ražu novācot, un pēc 2 un 4 mēnešiem. Pēc 4 mēnešu glabāšanas stingri āboli bija šķirnēm 'Fuji', 'Fiesta', 'Pinova', 'Topaz', 'Alwa', 'Gorjaczkowski Seedling' un 'XIX-133-D2'. Augsts šķīstošās sausnas saturs (>15°Brix) bija šķirnēm 'Redgold' un 'Golden Delicious', bet augsts titrējamo skābju saturs (>0.6%) - 'Topaz' un 'Gorjaczkowski Seedling'. Šķīstošās sausnas un skābju attiecība palielinājās glabāšanas laikā. Pēc 4 mēnešu glabāšanas augstākā attiecība bija šķirnēm 'Fuji', 'Gala' un 'Redgold' (>60) salīdzinoši zema (<30) šķirnēm 'Gorjaczkowski Seedling', 'Sawa', 'Topaz' un 'Witos'.

Abstract

The investigations were carried out in two successive seasons (2003/2004 and 2004/2005) on 29 apple cultivars obtained from trees on the rootstock M.9, which at the beginning of the investigation were six years old. The apples were picked when their starch index reached the values from 6 to 8. Fruit samples were stored for 4 months in a common cold storage at +2°C. At harvest and after 2, and 4 months of storage, firmness, titratable acidity and soluble solids were determined. Apples of the evaluated cultivars significantly differed in firmness and organic components content, shaping their internal quality. After 4 months of storage high firmness, independently of the season of determination, was characteristic for 'Fuji', 'Fiesta', 'Pinova', 'Topaz', 'Alwa', 'Gorjaczkowski Seedling' and 'XIX-133-D2' apples. A high soluble solids content (>15°Brix) was recorded in 'Redgold' and 'Golden Delicious' and a high titratable acidity (>0.6%) in 'Topaz' and 'Gorjaczkowski Seedling' apples. The ratio of soluble solids to organic acids increased with storage time. After 4-month of storage a very high value of that ratio was found in 'Fuji', 'Gala' and 'Redgold' (>60) and comparatively low (<30) in 'Gorjaczkowski Seedling', 'Sawa', 'Topaz' and 'Witos'.

Key words: apples, firmness, soluble solids content, titratable acidity

Introduction

According to currently binding standards fruits are evaluated on the basis of their external appearance, however, new standards include requirements concerning their internal quality traits. Apart from firmness, an important role is played by the soluble solids content and acidity, i.e. parameters affecting the fruit taste. The results of the investigations show that the internal qualitative traits of apples depend significantly on the cultivar (Szklarz and Pacholak, 2000; Skrzyński *et al.*, 2004) and on the time of storage (Błaszczyk, 1998). Konopacka and Płocharski (2002) point to the importance of the flesh firmness. They also report that the firmness of apples after storage is closely correlated with their firmness at the time of harvest. An important role is also played by organic acids which are substrates in fruit energetic reactions which is connected with systematic the decrease of acidity in stored apples (Ben, 1996).

The work aimed at comparing the firmness, the soluble solids content and the acidity of various apple cultivars during storage. The results of this evaluation may be useful for, among others, choosing progenous forms in breeding work.

Materials and Methods

The experiment was performed in two storage seasons (2003/2004 and 2004/2005). The investigations included 29 apple cultivars. In the first season the apple trees on the rootstock M.9 were six years old. They belonged to the cultivar collection of the Department of Pomology and Basic

Natural Sciences in Horticulture in Warsaw-Wilanów. The harvest time was set on the basis of starch test. Apples were picked when their starch index reached the values from 6 to 8. Fruit samples (about 50 apples of each cultivar per sample) were stored in a common cold storage at +2º C and relative air humidity of about 95%. The experiment was set in three replications. At harvest and after 2, and 4 months of storage, the firmness, titratable acidity and soluble solids were determined. Firmness was measured using an Instron penetrometer (type 5542) using standard piercing mandrel with the diameter of 11.3 mm. Soluble solids content was determined using Abbe refractometer. Juice acidity was determined by titration with 0.1 M solution of sodium hydroxide up to pH 8.1. Results were converted into the malic acid content. The data was used to calculate quantitative proportions between the soluble solids content and acidity. Results were analyzed statistically using one-factor variance analysis. Newman-Keuls test was used to evaluate the significance of differences between means at the significance level of $\alpha = 0.05$.

Results and Discussion

Apples of the evaluated cultivars showed significant variation in respect to all the examined traits.

Table 1. Apple firmness as influenced by cultivar and storage period

Cultivar	Firmness (N)					
	2003/2004			2004/2005		
	at harvest	after 2 months	after 4 months	at harvest	after 2 months	after 4 months
Alwa	82.8 gh*	70.0 ij	64.6 ij	79.7 efg	48.7 fg	45.0 de
Arlet	84.3 ghi	67.0 ij	49.9 g	76.0 defg	61.3 ijk	50.5 ef
Cortland	60.1 bcde	46.6 bcde	39.6 cde	65.2 abcd	40.3 cd	34.7 bc
Elstar	65.7 bcde	48.5 cdef	39.0 cde	63.9 abc	43.0 de	36.1 bc
Fiesta	83.3 gh	80.0 k	64.9 ij	69.2 bcde	60.2 ij	57.3 g
Freedom	63.6 bcde	50.8 def	38.7 cde	65.5 abcd	30.2 a	27.2 a
Fuji	78.0 fg	72.5 j	64.4 ij	82.5 fg	69.2 m	64.1 h
Gala	89.5 hi	68.3 ij	63.8 ij	86.7 g	60.5 ij	51.2 ef
Gloster	87.3 ghi	68.2 ij	61.3 hi	96.5 h	51.9 gh	45.7 de
Golden Delicious	69.0 def	50.5 def	40.3 cde	71.8 cdef	45.8 ef	46.5 de
Gorjaczkowski Seedling	98.0 j	90.6 l	64.5 ij	102.5 h	63.3 jk	53.9 fg
Jonamac	49.6 a	43.8 bcd	43.6 defg	54.8 a	37.1 bc	-
Laxton's Superb	69.0 def	52.2 def	46.7 efg	55.1 a	49.8 fgh	48.7 def
Ligol	58.5 abcd	56.0 fg	48.7 fg	58.2 ab	53.5 h	46.1 de
Melodie	54.1 ab	49.6 cdef	37.5 cd	58.2 ab	33.2 ab	-
Melrose	66.0 bcde	49.3 cdef	33.9 bc	76.7 efg	45.9 ef	42.5 d
Mutsu	82.6 gh	63.4 hi	46.2 efg	79.9 efg	49.0 fg	47.3 de
Odra	69.6 def	55.4 efg	41.6 cdef	77.9 efg	39.8 cd	35.9 bc
Pinova	66.8 cde	67.7 ij	56.8 h	86.3 g	64.8 kl	58.4 g
Rajka	65.0 bcde	47.1 bcdef	39.3 cde	55.5 a	32.7 ab	29.8 ab
Redgold	93.5 ij	75.3 jk	56.2 h	86.3 g	48.6 fg	48.6 def
Rubin	64.1 bcde	60.1 gh	46.8 efg	62.3 abc	39.7 cd	34.4 bc
Rubinette	61.6 bcde	40.0 b	34.6 bc	58.7 ab	35.6 bc	35.3 bc
Sawa	58.9 abcd	40.2 b	23.5 a	79.9 efg	32.9 ab	27.8 a
Selena	60.7 bcde	55.0 efg	34.4 bc	62.3 abc	37.5 bc	35.2 bc
Spartan	71.6 ef	71.2 ij	58.6 hi	71.2 cde	50.3 fgh	37.7 c
Topaz	82.3 gh	81.7 k	70.6 j	71.8 cdef	58.0 i	50.5 ef
Witos	55.2 abc	32.4 a	29.6 b	55.9 a	32.7 ab	30.3 ab
XIX-133-D2	65.5 bcde	69.0 ij	64.4 ij	69.6 cde	67.5 lm	57.9 g

*Mean separation, within the columns, by Newman Keuls test, at α=0.05

One of the most important quality factors, from the point of view of the consumer, is the flesh firmness. Out of all the evaluated cultivars a high firmness at harvest was characteristic for 'Gorjaczkowski Seedling' (98.0 and 102.5 N, respectively in the successive seasons), 'Redgold' (93.5 and 86.3 N), 'Gala' (89.5 and 86.7 N) and 'Gloster' (87.3 and 96.5 N) apples. Additionally high firmness after harvest in the second year of the investigation was observed in the 'Pinova' cultivar (86.3 N). Fruit harvested in 2004 became soft quicker during storage than the fruits harvested in the previous year. After 4 months of storage in the season 2003/2004 the significantly highest firmness was characteristic for 'Topaz' apples (70.6 N). At the same time high firmness was also observed in the fruit of 'Fiesta' (64.9 N) and 'Alwa' (64.6 N) cultivars. In the season 2004/2005 after 4 months of storage the most firm were 'Fuji', 'Pinova', 'XIX-133-D2' and 'Fiesta' apples. Regardless of the season of determination, the least firm apples at harvest were 'Jonamac' apples while 'Witos' and 'Sawa' apples became soft most quickly during storage and after 4 months were clearly less firm than apples of the remaining cultivars (Table 1).

Generally, apples picked in the season 2004 were characterized by a lower content of soluble solids and lower acidity as compared to those obtained in the year 2003. Lower soluble solids content and acidity most probably resulted from a cool summer in 2004.

Table 2. Apple soluble solids content as influenced by cultivar and storage period

Cultivar	Soluble solids content (°Brix)					
	2003/2004			2004/2005		
	at harvest	after 2 months	after 4 months	at harvest	after 2 months	after 4 months
Alwa	14.5 cdef*	14.6 cdefghi	14.4 cdef	12.4 abcd	12.7 bcd	12.9 bcde
Arlet	14.7 def	15.7 ijk	15.0 def	13.1 abcdef	13.1 bcdef	13.5 cdefg
Cortland	14.3 bcdef	14.9 defghij	14.2 bcdef	13.3 abcdef	13.4 cdefg	13.0 bcde
Elstar	14.6 cdef	15.3 ghij	15.6 f	13.5 bcdef	13.8 cdefgh	15.1 ij
Fiesta	14.0 abcde	15.5 hij	14.8 def	12.8 abcdef	13.1 bcdef	12.6 abc
Freedom	13.1 ab	13.3 ab	14.3 cdef	12.5 abcde	13.5 cdefg	12.3 ab
Fuji	15.8 ghi	15.9 jk	14.8 def	13.9 efg	14.3 fgh	12.9 bcde
Gala	14.9 efg	14.9 defghij	14.9 def	12.0 a	13.3 cdefg	12.7 abcd
Gloster	15.0 efg	15.1 fghij	14.8 def	12.6 abcde	14.3 fgh	13.9 efgh
Golden Delicious	16.0 hi	16.6 k	15.7 f	15.3 h	14.5 gh	14.8 hij
Gorjaczkowski Seedling	15.3 fgh	14.6 cdefghi	14.2 bcdef	13.7 def	14.3 fgh	13.8 defg
Jonamac	13.8 abcde	13.7 abc	14.8 def	13.6 cdef	13.0 bcde	-
Laxton's Superb	16.6 i	16.7 k	14.9 def	17.4 i	16.8 j	17.0 k
Ligol	14.3 bcdef	13.7 abc	13.8 abcde	13.4 abcdef	12.6 bc	12.7 abcd
Melodie	14.0 abcde	13.5 abc	12.8 ab	12.8 abcdef	13.6 cdefg	-
Melrose	12.7 a	13.1 a	13.0 abc	12.9 abcdef	13.7 cdefg	13.1 bcdef
Mutsu	14.5 cdef	15.0 defghij	13.7 abcd	12.9 abcdef	14.0 defgh	14.0 fgh
Odra	13.6 abcd	13.6 abc	13.1 abc	13.6 cdef	13.6 cdefg	14.3 ghi
Pinova	13.8 abcde	14.4 bcdefgh	13.6 abcd	14.9 gh	14.9 h	15.5 j
Rajka	14.7 def	15.3 ghij	15.3 ef	13.0 abcdef	13.2 cdef	11.9 a
Redgold	16.1 hi	16.5 k	16.8 g	15.7 h	16.0 i	15.3 j
Rubin	14.6 cdef	15.2 fghij	14.9 def	12.7 abcde	13.1 bcdef	13.7 defg
Rubinette	16.5 i	16.6 k	14.8 def	14.9 gh	14.1 efgh	14.4 ghi
Sawa	12.8 a	15.1 efghij	13.4 abcd	12.1 ab	12.0 ab	13.0 bcde
Selena	13.0 a	13.9 abcde	12.9 abc	12.2 abc	11.7 a	12.4 ab
Spartan	13.4 abc	14.7 cdefghij	14.6 def	12.4 abcd	14.1 efgh	13.7 defg
Topaz	14.6 cdef	14.7 cdefghij	14.6 def	13.1 abcdef	13.6 cdefg	13.7 defg
Witos	13.2 ab	13.8 abcd	12.7 a	12.2 abc	12.7 bcd	13.1 bcdef
XIX-133-D2	13.9 abcde	14.1 abcdefg	13.5 abcd	14.1 fg	12.9 bcde	16.8 k

* Mean separation, within the columns, by Newman Keuls test, at α=0.05

A high soluble solids content directly after harvest (>16º Brix in the year 2003 and >15º Brix in 2004) was characteristic for 'Laxton's Superb', 'Redgold' and 'Golden Delicious' apples (Table 2).

In the case of most apple cultivars, after two months of storage an increase of the soluble solids content was noted while after successive two months the value of this indicator decreased. In the season 2003/2004 after 4 months of storage the highest value of the soluble solids content was observed in 'Redgold' apples. In that season, a high content was also characteristic for 'Golden Delicious' and 'Elstar' fruits. On the other hand, low soluble solids content was noted, independently of the time of determination, in 'Melrose', 'Sawa' and 'Selena' apples (usually from 12 to 13º Brix). In the season 2004/2005 high soluble solids content after 4 months of storage was noted in 'Laxton's Superb', 'XIX-133-D2', 'Pinova' and 'Redgold' apples.

The effect of cultivar on the apple titratable acidity was proved at all times of analyses (Table 3).

Table 3. Apple titratable acidity as influenced by cultivar and storage period

Cultivar	Titratable acidity (% malic acid)					
	2003/2004			2004/2005		
	at harvest	after 2 months	after 4 months	at harvest	after 2 months	after 4 months
Alwa	0.90 lm*	0.67 hi	0.52 kl	0.44 abcd	0.39 bcdefgh	0.34 ef
Arlet	0.71 gij	0.76 ij	0.41 defghijk	0.48 abcde	0.45 efgh	0.35 ef
Cortland	0.63 cdefgi	0.53 defg	0.34 defghi	0.60 efgh	0.45 efgh	0.43 ghi
Elstar	0.67 efgij	0.63 gh	0.41 efghijk	0.63 fgh	0.70 ij	0.54 j
Fiesta	0.80 jkl	0.86 j	0.55 lm	0.48 bcde	0.36 abcdefg	0.34 ef
Freedom	0.64 defgij	0.53 defg	0.42 ghijkl	0.52 cdef	0.38 bcdefgh	0.27 bcde
Fuji	0.61 cdefgi	0.30 ab	0.15 a	0.32 a	0.23 a	0.20 ab
Gala	0.34 a	0.27 a	0.19 ab	0.32 a	0.28 abc	0.20 ab
Gloster	0.52 bcdef	0.54 efg	0.46 hijkl	0.44 abcd	0.35 abcdef	0.37 efg
Golden Delicious	0.66 efgij	0.49 cdef	0.38 defghij	0.69 ghi	0.40 bcdefgh	0.32 def
Gorjaczkowski Seedling	1.17 n	0.79 ij	0.63 mn	0.87 k	0.76 j	0.64 k
Jonamac	0.40 ab	0.26 a	0.21 abc	0.47 abcde	0.33 abcde	-
Laxton's Superb	0.73 gijk	0.61 fgh	0.36 defghi	0.56 defg	0.42 cdefgh	0.24 abcd
Ligol	0.54 bcdef	0.35 abc	0.31 cdefgh	0.43 abcd	0.30 abcd	0.27 bcde
Melodie	0.87 klm	0.64 gh	0.43 ghijkl	0.80 ijk	0.50 gh	-
Melrose	0.47 bc	0.43 bcde	0.42 fghijk	0.39 abc	0.36 abcdefg	0.33 ef
Mutsu	0.78 ijkl	0.47 cdef	0.33 cdefghi	0.46 abcde	0.33 abcde	0.32 def
Odra	0.64 defgij	0.48 cdef	0.43 ghijkl	0.78 ijk	0.62 i	0.45 hi
Pinova	0.52 bcdef	0.39 abcd	0.27 bcd	0.63 fgh	0.43 defgh	0.34 ef
Rajka	0.59 cdefg	0.52 defg	0.39 defghijk	0.42 abcd	0.33 abcde	0.22 abc
Redgold	0.51 bcde	0.32 ab	0.28 bcdef	0.33 ab	0.26 ab	0.18 a
Rubin	0.62 cdefgi	0.48 cdef	0.38 defghij	0.44 abcd	0.34 abcde	0.29 cde
Rubinette	0.94 m	0.68 hi	0.46 ijkl	0.63 fgh	0.48 fgh	0.40 fgh
Sawa	0.60 cdefg	0.68 hi	0.52 jkl	0.83 jk	0.51 h	0.49 ij
Selena	0.69 fgij	0.51 defg	0.37 defghi	0.51 cdef	0.42 defgh	0.32 def
Spartan	0.53 bcdef	0.41 bcde	0.27 bcde	0.42 abcd	0.35 abcdef	0.28 bcde
Topaz	0.99 m	0.83 j	0.65 n	0.80 ijk	0.63 i	0.49 ij
Witos	0.77 ijkl	0.69 hi	0.45 hijkl	0.71 hij	0.63 i	0.43 ghi
XIX-133-D2	0.48 bcd	0.36 abc	0.29 bcdefg	0.47 abcde	0.42 cdefgh	0.33 ef

* Mean separation, within the columns, by Newman Keuls test, at α=0.05

Both in the year 2003 and 2004 directly after harvest it was noted that 'Gorjaczkowski Seedling' apples were characterized by a significantly highest acidity which converted into the content of malic acid in the successive years amounted to 1.17% and 0.87%, respectively. Also 'Topaz' apples were characterized by high acidity independently of the year of investigations. On the other hand, 'Gala'

apples showed the lowest acidity (0.34% and 0.32%, respectively in the successive years of investigations). After 2 and 4 months of storage statistically the highest acidity was observed in 'Topaz' and 'Gorjaczkowski Seedling' apples and the lowest in 'Fuji' and 'Gala'. The rate of acidity decrease during storage depended to a high degree on the cultivar. The greatest decrease of that index in the season 2003/2004 was observed in 'Fuji' cultivar while in the successive season in 'Laxton's Superb'. On the other hand, in the case of 'Melrose' apples the decrease of acidity was slight amounting to about 10% in both seasons.

The proportion of the soluble solids content to acidity affects the taste of fruits. Apples in which the value of this proportion is too high may be evaluated by consumers as too sweet, while if the proportion of sugars to acids is too low, the fruits are sour. 'Redgold', 'Fuji' and 'Gala' apples were always characterized by a high quantitative proportion of soluble solids content to acidity which mostly resulted of their low acidity. The lowest value of this proportion was noted in 'Gorjaczkowski Seedling' apples (Table 4).

Table 4. Proportion of the soluble solids content to acidity as influenced by cultivar and storage period

Cultivar	2003/2004			2004/2005		
	at harvest	after 2 months	after 4 months	at harvest	after 2 months	after 4 months
Alwa	16.4 abcd*	22.0 abc	27.8 ab	28.3 defgh	32.3 abcd	37.7 cdef
Arlet	21.0 bcdefg	20.7 ab	37.0 abcde	27.7 defgh	29.2 abcd	39.5 def
Cortland	22.7 cdefgh	28.5 cdefg	41.5 bcdef	22.1 bcde	30.3 abcd	30.3 abcd
Elstar	22.1 cdefg	24.3 abcde	38.3 abcde	21.8 bcd	20.3 a	28.1 abc
Fiesta	17.6 abcde	18.2 a	26.9 ab	26.7 defgh	36.0 cde	38.6 def
Freedom	20.6 bcdefg	25.0 abcdef	34.3 abcd	24.2 cdefg	36.4 cde	45.3 efg
Fuji	25.8 gh	53.0 k	99.4 i	43.0 j	65.0 f	64.2 h
Gala	44.6 k	55.9 k	80.3 h	38.5 i	48.1 e	64.1 h
Gloster	29.0 hi	27.8 bcdefg	32.0 abcd	29.3 defgh	41.5 de	38.1 def
Golden Delicious	24.2 fgh	34.9 ghij	41.3 bcdef	22.5 bcdef	36.6 cde	46.6 efg
Gorjaczkowski Seedling	13.1 a	18.5 a	23.0 a	15.7 ab	18.9 a	21.7 a
Jonamac	35.9 j	52.3 k	69.4 g	28.8 defgh	39.4 de	-
Laxton's Superb	22.9 defgh	27.5 bcdefg	41.8 bcdef	31.5 gh	40.7 de	72.6 i
Ligol	26.7 ghi	39.2 j	44.4 cdef	31.2 gh	42.2 de	46.7 efg
Melodie	16.1 abc	21.3 abc	29.9 abcd	16.2 ab	27.5 abcd	-
Melrose	27.3 ghi	30.4 defgh	31.4 abcd	33.6 h	38.1 de	40.8 def
Mutsu	18.9 abcdef	32.3 fghi	41.8 bcdef	28.1 defgh	42.0 de	44.1 efg
Odra	21.4 cdefg	28.7 cdefg	30.7 abcd	17.5 abc	21.8 ab	32.3 bcd
Pinova	26.8 ghi	37.2 ij	51.5 ef	23.7 cdefg	34.3 bcde	46.2 efg
Rajka	25.0 fgh	29.2 cdefg	39.3 bcdef	30.6 gh	40.7 de	54.1 g
Redgold	31.8 i	52.2 k	66.5 g	48.2 k	62.6 f	85.6 j
Rubin	23.8 efgh	32.0 efghi	38.8 abcde	28.6 defgh	41.2 de	46.6 efg
Rubinette	17.5 abcde	24.4 abcde	32.6 abcd	23.7 cdefg	29.2 abcd	36.6 cde
Sawa	21.5 cdefg	22.7 abcd	26.6 ab	14.5 a	23.5 abc	26.6 ab
Selena	19.1 abcdef	27.4 bcdefg	35.3 abcd	23.8 cdefg	27.7 abcd	39.0 def
Spartan	25.6 fgh	36.0 hij	53.6 f	29.5 efgh	41.1 de	48.7 fg
Topaz	14.7 ab	17.8 a	22.6 a	16.5 ab	21.4 ab	28.0 abc
Witos	17.2 abcde	20.1 ab	28.4 abc	17.5 abc	20.2 a	30.3 abcd
XIX-133-D2	29.0 hi	39.2 j	46.1 def	29.9 fgh	30.9 abcd	51.4 g

* Mean separation, within the columns, by Newman Keuls test, at α=0.05

Conclusions

The sinvestigated apple cultivars were characterized by a great differentiation of the flesh firmness. The highest firmness after storage in the season 2003/2004 was characteristic for 'Topaz' apples while in the season 2004/2005 significantly the most firm were 'Fuji' apples.

High soluble solids content (over 15ºBrix) were observed in 'Redgold' and 'Golden Delicious' apples while high acidity (over 0.6%) was characteristic for 'Topaz' and 'Gorjaczkowski Seedling' apples.

With storage time a mutual quantitative proportion of the soluble solids content to acidity increased. The highest values of that proportion were shown by 'Fuji' and 'Gala' apples. It may affect the length of their storage period and also determine their evaluation by consumers.

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