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PARAMETRII DE CALITATE FIZICO-CHIMICI AI FRUCTELOR UNOR SOIURI NOI DE MĂR

FRUIT PHYSICO-CHEMICAL QUALITY PARAMETERS OF NEW INTRODUCED APPLE CULTIVARS

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Abstract

The apple fruit is the second most frequently consumed, after bananas and some quality characteristics like size, gloss, color, and aroma influenced directly the flesh consumption. In this study, the external (weight, size, skin colour) and internal (firmness, total soluble solids, acidity, pH) fruit quality attributes were measured experimentally before the storage, using well defined techniques. 'Corelita', 'Coreal', 'Corealor', 'Coredova', 'Corejuno', 'Coretard', 'Coreagat', 'Coreor' and 'Coreprim' cultivars were registered, in the last 15 years, by Practical Scientific Institute of Horticulture and Food Technologies Chișinău, Republic of Moldova, as scab resistant varieties. The orchard trial was established at the Research Institute for Fruit Growing Pitesti, Romania in the spring 2014 on MM106 rootstock, at the spacing of 3.5 x 2 m and fruit samples were analyzed in 2019, 2020 and 2021 seasons. All studied cultivars were harvested before 'Florina' cv., used as control. Fruit weight was quite variable among genotypes, between 115.15 g at 'Coreal' cv. and 212.41 g at 'Corejuno', and most of the cultivars had smaller fruits than 'Florina' cv. Firmness and total soluble solids varied from 70.5 to 82.61 N and 12.77 to 16.77%Brix. The Hunter color values *L, a, b*, were found to be in the range of 46.12 to 56.76, - 6.46 to 14, 13.75 to 23.72, respectively. The data about the external and internal fruit quality of new Moldavian scab resistant apple cultivars are useful for growers, in order to introduce in the new orchards only cultivars with high quality fruits.

Cuvinte cheie: *Malus domestica*, Moldova, mărime fruct, culoare epidermă, fermitate, compuși biochimici
Key words: *Malus domestica*, Republic of Moldova, fruit size, skin colour, firmness, biochemical compounds

1. Introduction

Apple (*Malus domestica* [Suckow] Borkh.) is one of the most important horticultural crop grown in temperate areas and most commonly consumed fruits in the world (Ferre and Warrington, 2003; Muneer et al., 2017). It belongs to the family of *Rosaceae* and subfamily *Pomoideae*, having more than 7,500 apple cultivars, but only about 20 cultivars are commercially important (Spengler, 2019).

The quality of an apple fruit can be characterized by different attributes like sensory, physical, chemical, mechanical, but, at first instance, it is judged by appearance comprising colour, gloss, size, and secondly by texture, total soluble solids content and titratable acidity (Drogoudi et al., 2008).

Apples are mostly consumed as fresh due to storable capacity and harvested from early summer (July) to late autumn (October). Based on ripening stage, the cultivars are classified as summer, autumn and winter apples. A low percentage of them are consumed immediately after harvesting, but a large part is stored for few months. During storage, apple quality changes rapidly and affects the acceptability of consumers (Johnston et al., 2001; Vieira et al., 2009).

Apples are the largest fruit crop in Moldova: 60% of fruit production and more than 300,000 tons. Around 80% of apples are sold as fresh product while the surplus apples and apples of poor qualities are used by the processing industry, mainly to produce concentrate apple juice. Grown mostly in the Central and Northern regions of the country, Moldovan apples have long been a staple in Eastern markets. While consumers have enjoyed these apples for decades during the Soviet era, Moldovan producers are now looking for new markets as the Russian markets are almost closed due to the embargo (JICA report, 2017).

In the last 15 years, the Practical Scientific Institute of Horticulture and Food Technologies Chișinău, Republic of Moldova (Victor Bucarciuc and Borozneț I. A.) in collaboration with Institute of Fruit Breeding Dresden-Pillnitz, Germany (Christa Fisher) registered new scab resistant varieties. The cultivars of the 'Core-series' ('Co' = collaboration and 're' = resistance) represent the combination of high practical value of fruit quality with good storage and scab resistance ((Bucarciuc, 2010, 2017) .

The aim of this research was to evaluate, at harvest maturity, external and internal fruit quality attributes of new scab resistance apple cultivars from Republic of Moldova in comparison with 'Florina' cv.

Based on these results, apple growers can get guidelines for selecting the best planting material according pedoclimatic conditions.

2. Material and methods

2.1. Plant material and sampling

The Practical Scientific Institute of Horticulture and Food Technologies Chișinău, Republic of Moldova registered, in the last 15 years, nine apple scab resistant cultivars: 'Corelita', 'Coreal', 'Corealor', 'Coredova', 'Corejuno', 'Coretard', 'Coreagat', 'Coreor' and 'Coreprim'. In the spring of 2014, at the Research Institute for Fruit Growing Pitesti, Romania, an experimental orchard using one-year-old trees grafted on MM106 was planted. The location is characterized by an average yearly temperature of 10^0C, average rainfall of about 678 mm and altitude about 290 m. The tested cultivars (Table 1, Fig. 1) were placed as single rows or as a part of the row, with 3.5 m between rows and 2 m between trees. The control scab resistant apple cultivar 'Florina', grown worldwide, was included to study, also. The orchard was maintained with clean herbicide strips under the tree canopies, with mulched grass along the alleyways and under non-irrigated standard cultural practices. At phenological growth stage BBCH87 – Fruit ripe for picking (Meier, 2001), samples from each cultivar (30 fruits / cv.) were picked homogenously and analyzed in the lab.

2.2. Pedo-climatic conditions

The experimental field was located on a flat land, of alluvial type, soil with medium texture, pH around 6. The humus content is relatively low: 1.50% at the surface, 0.90% at 60 cm depth and 0.61% in the Bg horizon.

During the study period, from January, 2019 till September, 2021, the annual average temperature was 12.0^{o}C (with 2.0^{o}C higher than the multiannual average temperature of the area of 51 years - respectively, 10.0^{o}C) ranging between 11.8^{o}C in 2019 and 12.58^{o}C in 2021 (until September). The average annual rainfall was 683.3 mm, ranging between 634.7 mm in 2019 and 679.1 mm in 2020, being very close to the multiannual average of rainfall from the area (678 mm).

2.3. Measurement of external quality

The starch index was determined by spraying on half horizontally around its equator cut fruits with iodine solution in potassium iodide and evaluation of ripeness after a scale of 1C to 10C, where 1C = immature, 2C, 3C, 4C = unripe, 5C, 6C, 7C = ripe, 8C, 9C, 10C = overripe (The CTIFL, France - Starch conversion chart for apples).

The weight of the apple was measured using an electronic weighing balance (OAP-6-MA, Universal Weight Enterprise) having the least unit of 0.001 g;

The diameter of fruits (mm) was measured using a calibrator;

The chromameter Konica Minolta CR-400 was used to measure the fruit color in CIELAB system. The color of each apple was measured at two equally distant places across the height of the apple, and mean values were recorded. The maximum for '*L*' is 100, which represents a perfect reflecting diffuser. The minimum for L* is zero, which represents black. So, '*L*' indicated the lightness or darkness, '*a*' indicated the redness or greenness and '*b*' indicated the yellowness or blueness of the samples.

2.4. Measurement of internal quality

The firmness of the apple was measured using a non-destructible penetrometer (Bareiss Qualitest HPE-II-FFF, Germany), at two distant places (near the equator) on each side of the apple, and average values were reported. 5 mm diameter cylindrical probe was used to perform the penetration test;

For measurement of soluble solids content (SSC), malic acid content and pH, the juice of the apple was extracted using a domestic juice extractor and was filtered through a cotton cloth. The SSC (%Brix) was measured using the Hanna HI 96801 portable refractometer. Malic acid content and pH were measured using Hanna HI 84532 minititrator.

2.5. Statistical analysis

Data were analyzed by Duncan multiple range test. The level of significance was defined as $P \leq 0.05$. Correlation analysis was also performed in order to determine the relationships among fruit quality parameters.

3. Results and discussions

External fruit quality

Table 2 shows mean values of starch index, fruit's diameter, weight and coloration of studied cultivars.

The starch index had the average value of 6.43, ranging from 5.6 at 'Coredova' cv. and 6.9 at' Florina' cv., all the cultivars being at an appropriate stage of maturity (Table 2).

Fruit weight is a quantitative parameter, being influenced by cultivar and environmental conditions (Comai et al., 2005). The data resulting from the three years of study showed that the weight values of

Moldavian cultivars ranged from 115.15 g ('Coreal' cv.) to 212.41 g ('Corejuno' cv.). Results indicated statistically significant differences among cultivars and a wide range variability of this trait. The most variable in the diameter of fruits was 'Coreor' cv. that noted 67.66 mm in one year and only 58.92 mm in another. The fruit weight was significantly higher in 2020 than 2019 and 2021, 2020 being a rainier year (Table 2). Among the cultivars studied, only the 'Corejuno' cv. had larger fruits than the control cv. 'Florina' (212.41 g at 'Corejuno' cv. versus 169.57 g at 'Florina' cv.). The results regarding fruit weight are similar to those presented by Bucarciuc on 'Corealita' 'Coreagat' and 'Coreprim' cvs. On the 'Coreor', 'Coredova', 'Coreal', 'Coretard' and 'Corealor' cvs., the results obtained in this study were slightly smaller than those obtained by Bucarciuc. Regarding 'Corejuno' cv. the fruit weight in Romanian climatic conditions was higher than the one reported by Bucarciuc in the climatic conditions of the Republic of Moldova (Bucarciuc, 2010 and 2017).

Color is also an important quality parameter that directly affects appearance and consumer acceptability (Pathare et al., 2013). Color intensity depends on the cultivar due to pigments content, like anthocyanins. According to the CIELAB color scale it is noted that, there are significant differences between cultivars. It is known that, when approaching of optimum maturity, cultivars become more lightness (L*), redder (a*) and bluer (b*). The lightness ('*L*' value) is ranging from 46.12 at 'Corealor' cv. to 56.76 at 'Corejuno' cv. The '*a*' value, indicating green color of the skin, registered negative values for 'Coretard', 'Coreal' and 'Corejuno' cvs. The smallest value was registered for 'Corejuno' cv. (-6.46) with bicolor skin. The yellowness index ('*b*' value) varied from 13.75 for 'Coreagat' cv. to 23.72 for 'Coreal' cv. (Table 2). During the three years of study, the most colorful fruits were obtained in 2019 (L* = 49.39) and the least colored in 2020 (L* = 53.59) (Table 3).

'Corelita', 'Coreal', 'Coredova' and 'Corejuno' cvs. were noted by the more colorful fruits than control 'Florina' cv.

Internal fruit quality

Tables 4 and 5 show firmness, total soluble solids, pH and malic acid content of new Moldavian apple cultivars compared with 'Florina' cv.

For apples, the *fruit firmness* is considered as a major quality parameter that indicates the storage capacity. The firmness is correlated with the skin thickness, an important characteristic for harvesting, transport and consumers. Statistical analysis of data on fruit firmness, show that, between cultivars studied was some significant differences. We found fruit firmness values of Moldavian are range between 70.50 HPE units for 'Coreor' cv. and 82.61 HPE units for 'Coreagat' cv. Except for 'Coreor' and 'Coreprim' cvs., all other Moldavian cultivars were much firm than 'Florina' cv. (control). The average fruit firmness had close values in the three years of study.

Soluble solids content is considered as a good indicator of the sugar content of apples and presumably of sweetness (Hoehn et al., 2003). For apple studied cultivars, the SSC is between 12.77%Brix ('Coredova' cv.) and 16.77%Brix ('Coreal' cv.). The control cultivar, 'Florina', registered 14.21 %Brix, which is considered as a high value in comparison to other apple cultivars. It was reported that an apple cultivar with the highest SSC (13.9%Brix,) in comparison to 'Golden Delicious' cv. (13.7%Brix) and 'GoldRush' cv. (12.9%Brix) (Leccese et al. 2009, Petkova et al., 2019). Among the apple cultivars of Moldavian origin were remarked by higher content in the soluble solids content (over 14%), the following cultivars: 'Coreal', 'Corealor', 'Corejuno' and 'Coretard'. Making a comparison between the results obtained in our study and those obtained by Bucarciuc in 2010 and 2017, it is observed that on some cultivars ('Corelita', 'Coredova' and 'Corealor') the soluble solids content of fruits was lower in Romania than in Moldova and on others cultivars ('Coreal' and 'Coretard') was higher in Romania than in Moldova. On 'Corejuno' and 'Florina' cvs. the content of fruits in soluble solids was similar to the one obtained by Bucarciuc in Moldova. Year by year variation of soluble solids was no significant but was higher in 2019 than 2020 and 2021 (Table 4).

Regarding pH, some authors report that the pH of apples has values between 3 and 4. In our study, the values of fruits pH ranged between 3.64 (‘Coreprim’ cv.) and 4.27 (‘Coreor’ cv.). Fruits pH was higher in 2019 than in 2020 and 2021 (Table 5).

The main organic acid in apple fruits is malic acid, as its content is up to 90% of the total organic acids (Wu et al., 2007). In apple cultivars with high amounts of malic acid, the sour taste becomes predominant (Wojdylo et al., 2008). During three years, the highest content of malic acid had 'Coretard' cv. (1.02 g/100 g fresh weight) and the lowest values were registered for 'Corejuno' (0.42 g/100 g fresh weight) and 'Florina' (0.52 g/100 g fresh weight) (Table 5). These results are similar with results obtained by Bucarciuc in 2010 and 2017. Mezey and Mezeyova (2018) reported that malic acid content measured in 'Florina' cv. has the lowest value 1.4±1.9 g/L in comparison with other 25 late ripening cultivars from Slovakia.

Correlations between fruit quality characteristics

Comparing the external and internal characteristics of the fruits, some significant correlations were found. For example, fruits weight was positively correlated with fruits diameter (r=0.590***) and negatively with malic acid content (r=-0.242º). This correlation indicates that large fruits are less acidic. Fruits diameter was positively correlated with firmness (r=0.241*). This correlation indicates that large fruits are firmer.

Fruits firmness was positively correlated with malic acid content (r=0.229*), which means that fruits firm are more acidic. Soluble solids content of fruits was negatively correlated with a* parameter (r=-0.327ºº) and positively with b* parameter (r=0.225), which means that the colorful fruits are sweeter (Table 6).

4. Conclusions

The data about the external and internal fruit characteristics of new Moldavian scab resistant apple cultivars are useful for growers in order to introduce in the new orchards only cultivars with high quality fruits and also for breeder in order to select the possible genitors in cross combinations.

Thus, in this study the following apple cultivars were noted: 'Corejuno' and 'Corelita' by large fruits; 'Coretard', 'Coreagat' and 'Corelita' by high fruits firmness; 'Coreal', 'Corealor' and 'Coretard' by high soluble solids content of fruits; 'Corelita', 'Coretard' and 'Coreagat' by high malic acid content of fruits.

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Tables and Figures

Table 1. Origin of Moldavian apple cultivars studied

Cultivar	Reported parentage	Year released
Corelita	$PR_{12}T_{67}$ x Golden Delicious	2007
Coreal	Juno x $OR_{33}T_{90}$	2010
Corealor	Juno x $OR_{33}T_{90}$	2010
Coredova	$OR_{38}T_{17}$ X Golden Delicious	2010
Corejuno	Juno x $OR_{33}T_{90}$	2010
Coretard	Juno x $OR_{33}T_{90}$	2010
Coreagat	Juno x $OR_{33}T_{90}$	2011
Coreor	$OR_{33}T_{90}$ x $OR_{38}T_{17}$	2013
Coreprim	$OR_{38}T_{17}$ x R_2T_{110}	2013
Florina (Ct)	(Jonathan x (Starking Delicious[a] x (Golden Delicious x F2 26829-2-2[b]))	1977

[a]Starking Delicious = sport of Red Delicious; [b]F2 26829-2-2 = (Rome Beauty x *M. floribunda* 821) x (Rome Beauty x *M. floribunda* 821); Ct = control

Table 2. The mean value of fruit size

Cultivar	Starch index	Diameter* (mm)				Weight* (g)			
		2019	2020	2021	Average	2019	2020	2021	Average
Corelita	6.6	85.66	73.33	75.97	78.32 a**	189.33	149.80	159.40	166.17 b
Coreal	7.4	70.00	71.00	72.43	71.14 bc	109.10	124.63	111.73	115.15 e
Corealor	7.2	74.30	73.66	60.10	69.36 c	144.30	148.70	104.33	132.44 cd
Coredova	5.6	71.00	70.66	70.52	70.73 b	119.10	159.56	142.56	140.57 c
Corejuno	5.9	-	79.33	76.81	78.07 a	-	214.00	210.83	212.41 a
Coretard	6.2	71.66	71.00	-	71.33 bc	126.40	133.36	-	129.88 cde
Coreagat	5.8	77.00	74.33	80.13	77.15 ab	156.23	153.33	163.60	157.72 b
Coreor	6.3	67.66	60.66	58.92	62.41 d	121.56	116.73	120.36	119.55 e
Coreprim	6.5	80.33	64.00	69.38	71.23 bc	187.26	129.40	159.03	158.56 b
Florina (Ct)	6.9	62.12	78.56	63.56	68.08 cd	161.93	196.40	150.40	169.57 b
Average	**6.43**	**73.30**	**71.65**	**69.76**		**146.13**	**152.59**	**146.92**	

*****Values represent the mean of 30 individual measurements; Values in the same column not connected by the same letter are significantly different (P ≤ 0.05); ** Duncan's multiple range test.

Table 3. The mean value of fruit color

Cultivar	CIELAB color values* (average 2019-2021)		
	L*	***a****	***b****
Corelita	54.73 a	5.18 ab	22.79 a
Coreal	54.36 a	- 4.21 d	23.72 a
Corealor	46.12 c	10.10 a	18.20 bc
Coredova	56.06 a	1.58 bc	21.73 abc
Corejuno	56.76 a	- 6.46 c	21.16 abc
Coretard	51.19 abc	- 3.82 c	22.19 ab
Coreagat	50.75 bc	9.37 ab	13.75 d
Coreor	48.38 bc	12.22 a	17.52 cd
Coreprim	53.11 ab	14.00 a	17.62 cd
Florina (Ct)	53.22 ab	10.47 a	20.04 abc
Average	**52.47**	**4.84**	**19.87**

*****Values represent the mean of 30 individual measurements; Values in the same column not connected by the same letter are significantly different (P ≤ 0.05); ** Duncan's multiple range test.

Table 4. The mean value of internal fruit quality (firmness and SSC)

Cultivar	Firmness* (HPE units)				SSC* (%Brix)			
	2019	2020	2021	Average	2019	2020	2021	Average
Corelita	77.58	79.08	81.96	79.54 ab	15.33	12.40	14.10	13.94 cde
Coreal	77.31	79.81	79.78	78.97 ab	16.56	17.23	16.53	16.77 a
Corealor	82.31	76.75	76.71	78.59 ab	16.43	17.76	14.56	16.25 ab
Coredova	78.71	77.91	81.18	79.27 ab	14.90	11.76	11.66	12.77 e
Corejuno	-	76.78	76.28	76.53 b	-	14.53	15.16	14.85 bcd
Coretard	80.05	81.16	-	80.60 ab	14.16	16.66	-	15.41 abc
Coreagat	83.33	82.86	81.65	82.61 a	13.40	12.00	13.06	12.82 e
Coreor	68.18	75.40	67.91	70.50 c	14.56	11.63	14.40	13.53 de
Coreprim	72.58	74.28	66.03	70.96 c	14.00	12.73	12.86	13.19 de
Florina (Ct)	76.40	74.05	76.67	75.70 b	14.20	13.63	14.50	14.21 cde
Average	**77.38**	**77.81**	**76.46**	**-**	**14.84**	**14.03**	**14.09**	**-**

*Values represent the mean of 30 individual measurements; Values in the same column not connected by the same letter are significantly different (P ≤ 0.05); ** Duncan's multiple range test.

Table 5. The mean value of internal fruit quality (pH and malic acid)

Cultivar	pH*				Malic acid* (g / 100 g fresh weight)			
	2019	2020	2021	Average	2019	2020	2021	Average
Corelita	4.4	4.4	3.3	4.06 abc	0.80	1.03	1.02	0.95 ab
Coreal	4.5	3.7	3.7	3.98 abc	0.54	0.85	0.80	0.73 c
Corealor	4.1	3.9	3.3	3.77 bc	0.88	0.88	0.84	0.86 abc
Coredova	4.6	4.7	3.5	4.26 a	0.77	0.87	0.80	0.81 bc
Corejuno	-	3.7	4.0	3.86 bc	-	0.43	0.42	0.42 d
Coretard	4.4	3.6	-	4.00 abc	0.61	1.04	-	1.02 a
Coreagat	4.4	4.7	3.4	4.17 ab	1.04	0.68	1.09	0.93 ab
Coreor	4.5	4.4	3.8	4.27 a	0.62	0.72	0.78	0.70 c
Coreprim	3.7	3.8	3.4	3.64 c	0.81	0.82	0.86	0.83 bc
Florina (Ct)	3.7	3.7	3.8	3.75 bc	0.52	0.51	0.55	0.52 d
Average	**4.25**	**4.06**	**3.58**		**0.67**	**0.78**	**0.78**	

*Values represent the mean of 30 individual measurements; Values in the same column not connected by the same letter are significantly different (P ≤ 0.05); ** Duncan's multiple range test.

Table 6. Correlation matrix among variables studied

Correlations	Weight	Diameter	SSC	Firmness	pH	Malic acid	L*	a*	b*
Weight	1	0.590***	-0.120	-0.013	-0.124	-0.242º	0.204	-0.043	-0.007
Diameter		1	0.177	0.241*	0.022	0.094	0.180	-0.196	0.091
SSC			1	0.002	-0.125	0.047	-0.068	-0.327ºº	0.225*
Firmness				1	0.096	0.229*	-0.039	-0.133	0.010
pH					1	-0.195	-0.089	-0.250º	0.124
Malic acid						1	-0.018	0.017	-0.084
L*							1	-0.542ººº	0.573***
a*								1	-0.552***
b*									1

*** Correlation is significant at the 0.001 level (2-tailed); *** Correlation is significant at the 0.01 level (2-tailed); *** Correlation is significant at the 0.05 level (2-tailed)

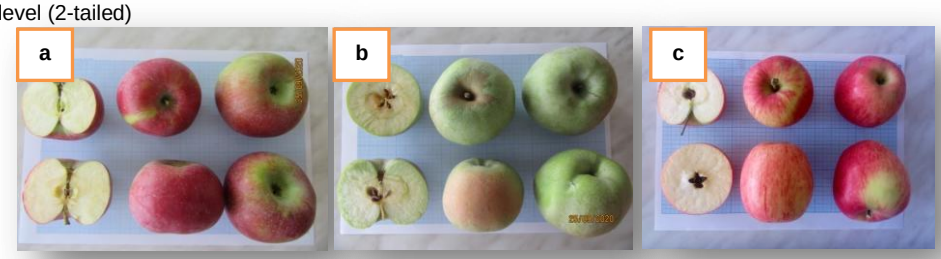

Fig. 1. New Moldavian apple cultivars (a – 'Coreagat'; b – 'Corejuno'; c – 'Corelita')