Productive manifestations and technological parameters of juice of selected yellow-green apple hybrids

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Citation
Sotirov, D., Dimitrova, S., Sotirov, A., & Zhelyazkov, P. (2022). Productive manifestations and technological parameters of juice of selected yellow-green apple hybrids. *Bulgarian Journal of Crop Science, 59*(5)75-80.

Abstract
The purpose of the present study was to evaluate the productivity, fruit quality, and suitability for technological processing of the fruits of apple selections with yellow-green fruit color for the production of cold-pressed cloudy juice. The study was conducted during the period 2018–2021 with 10 apple selections of the Institute of Agriculture - Kyustendil and three hybrids introduced from China through existing agreements on bilateral scientific and technical cooperation on apple cultivar selection and improvement. Juice obtained from each of the assessed apple hybrids and two standard cultivars was produced by cold pressing. The following indicators were determined: juice yield, total sugar content, total acidity, oxidation reduction potential, conductivity, total dissolved solids, salts, and relative weight. Sensory tests of color, aroma, and taste were performed. The ratios between the values of the aforementioned parameters were calculated. We established that hybrids 2/4 and 4/15 were the most suitable for the production of apple juice by the cold pressing method, yielding juice with an excellent taste and organoleptic qualities, color and aroma. Additionally, the highest yield of juice was obtained from these hybrids. Meanwhile, hybrid 4/15 produced exclusive quality juice, which could be defined as premium or luxury. The hybrid 1/14 did not produce juice, by cold pressing but a pulp-like suspension (puree). Therefore, all other studied hybrids can be used for the production of fruit juices by the cold pressing method. Nevertheless, the pre-processing addition of fruits of other, high juice-yielding apple cultivars or fruit species is desirable for achieving better juice quality and quantity.

Key words: apple selections; yield; juice; quality; technological characteristics

INTRODUCTION

The cultivar is one of the most dynamic elements in the fruit production that exerts a direct impact on production quantity and quality. Hence it has been the subject of active selection activities, aimed to improve both the quality of already established cultivars and to create new cultivars with promoted biological and economic qualities.

The abundant content of important to human health nutrients places apples among the most nutritious and valuable edible fruits. The fruit composition is characterized by the presence of high amounts of physiologically active chemical constituents, such as sugars, organic acids, mineral salts, tannins, vitamins, pectin, enzymes and other bioactive components which are of high significance for human health, especially in winter (Campeanu et al., 2009). The content and ratios of various chemical ingredients affect fruit taste, internal qualities, appearance and aroma (Treutter, 2001; Wicklund et al., 2021).

The main criteria affecting fruit appearance are its basic and cover color, shape and size. Taste is one of the most important indicators that is influenced by various fruit quality attributes. The most impor-

tant among these indicators are the fruit flesh structure, firmness, juiciness and the sugar and acid content. Flesh firmness and sugar content are important quality parameters that directly affect consumer's decision on purchasing fresh apple fruit (Yankun & Renfu, 2006; Harsan et al., 2006).

The apple cultivars have different technological characteristics, and are used in the food industry for the production of various products - juices, syrups, nectars, purees, wine, vinegar, cider, malic acid, pectin, fruit flours, dried fruits, compotes, marmalades, etc. (Laurens, 1999; Sedov et al., 2010).

The purpose of the present study was to evaluate the productivity, fruit quality, and suitability of some apple selections with yellow-green fruit color for the production of cold-pressed cloudy juice.

MATERIAL AND METHODS

The study was conducted during the period 2018–2021 with 10 apple selections of the Institute of Agriculture - Kyustendil and three hybrids introduced from China via bilateral scientific and technical cooperation on apple breeding activities. The orchard was planted with trees grafted on MM 106 rootstock, grown as free growing crowns and spaced at 4.5 × 2.5 m. Each selection was represented with five trees and each individual tree was treated as a replicate. All tested hybrids had yellow-green color of the fruit. Golden Delicious and Granny Smith were used as standard cultivars. The experimental trees were in a period of full bearing and were grown under a conventional production system. The following parameters of the trees of each selection were assessed: yield (kg/tree), average fruit weight (g), flesh firmness (kg/cm^2) and fruit-ripening period length.

A detailed biochemical analysis of the fruits was conducted to determine their technological suitability for the production of cold-pressed apple juice in two consecutive years (2020–2021). Apple juice (100%) was obtained by the method of cold pressing with a single-shaft juicer Star Light SJB-150 R (Company STAR LIGHT, Nice, France), unpasteurized, without additives. The following portable digital instruments were also utilized for the experimental measurements: Brix refractometer Milwaukee MA871 to measure the total sugar content by Brix (%) (Milwaukee Electronics Ltd, Szeged – Hungary); "SensoDirect 150" apparatus and EzDo 7011 „Waterproof" pH мeter (Lovibond Water Testing Tintometer® Group – Germany) were used for determination of total acidity (pH), electrical conductivity (μS), total dissolved solids - TDS (ppm), total salt content (ppm), and oxygen redox potential - ORP (mV). The relative weight of the juice was measured by a universal aerometer. The juice yield (%) was calculated, i.e. the ability of apples to release juice by cold pressing of the fruits, as the measurements of the average samples of 2.5 kg apples and the juice, obtained during the pressing were measured with a laboratory analytical balance. Sensory testing was then performed to establish parameters, such as the taste, aroma, color and turbidity of the juice, in compliance with the Regulation on the requirements for fruit juices and certain similar products intended for human consumption, published in Bulgarian State Gazette №100/13 in 2013.

The results of the fruit biometric measurements were statistically analyzed using analysis of variance (ANOVA) and the differences among the means were assessed by LSD test at $p \leq 0.05\%$ using the statistical software SPSS for Windows 10 (SPSS Inc., Chicago, IL, USA).

RESULTS AND DISCUSSION

The average data on trees yield showed that the studied hybrids had good to very good productivity that did not differ significantly from that of the standard cultivars Golden Delicious and Granny Smith. The highest yield per tree was realized by hybrids 2/28 and 8/22, whereas the lowest was obtained from hybrids 152 and 2/4 (Table 1).

The hybrids 2/8 and 8/22 had the largest fruits (212 and 208 g, respectively), whereas the smallest fruits were obtained from hybrid 2/4 (104 g). The fruits of all selections were crispy with fruit flesh firmness ranging from 6.9 to 10.1 kg/cm^2, which did not differ significantly from that of Golden Delicious and Granny Smith.

The fruits of hybrid 2/17 ripened the earliest - around mid-August and it belongs to the group of summer apple cultivars. Selections 1/7 and 1/14 ripened in the last ten days of August and the first ten days of September and they are considered typical autumn cultivars. The rest of the examined hybrids ripened from the second ten-day period of Septem-

Table 1. Physical parameters and ripening time of the fruit of the studied apple hybrids, average for 2018–2021

Hybrids	Pedigree	Yield, kg/tree	Fruit weigh, g	Flesh firmness, kg/cm^2	Date of harvest
№ 6	(Hongro - open pollination)	22.1 abc	125 de	8.5	20.09–02.10
№ 9	(Honglu × Senshu)	25.8 ab	187 ab	9.1	01.10–08.10
№ 152	(G. Delecious × Qianqiu)	11.5 c	150 cd	8.3	27.09–02.10
№ 1/3	(Mollie's Delicious – o.p.)	25.4 ab	142 cd	8.7	29.09–04.10
№ 1/7	(Winesap × Prima)	17.1 bc	130 de	6.9	31.08–13.09
№ 1/14	(Weinsep × Belgolden)	19.6 abc	136 de	7.8	17.08–25.08
№ 2/4	(Sekai Ichi × Gala)	16.2 bc	104 e	7.7	23.09–04.10
№ 2/8	(Summer Red × Erwin Bauer)	18.4 abc	212 a	8.8	27.09–03.10
№ 2/17	(Weinsep × Belgolden)	23.7 ab	196 ab	9.2	08.08–20.08
№ 2/28	(Prima × Florina)	28.9 a	148 cd	7.3	27.09–03.10
№ 2/30	(Prima × Sekai Ichi)	18.5 abc	188 cd	10.1	12.09–18.09
№ 4/15	(Pinova × Fuji)	20.9 abc	151 cd	7.5	18.09–27.09
№ 8/22	(chance seedling)	27.1 ab	208 a	8.3	23.09–30.09
G. Delicious (st)	(seedling of Grimes Golden)	21.3 abc	173 bc	7.3	25.09–30.09
G. Smith (st)	(chance seedling)	18.5 abc	204 ab	10.4	08.10–18.10

ber and the first week of October, belonging to the group of winter cultivars.

The technological parameters of the tested hybrids, important for the production of cold-pressed apple juice, are presented in Table 2. It is visible that the juice produced from the studied hybrids by cold pressing is less than 50%, which makes them unsuitable for self-production of juice. According to the Bulgarian ordinance on the requirements for fruit juices, this quantity must be at least 50% of the volume of the processed raw material (Bulgarian State Gazette №100/2013). In this respect, hybrid № 4/15 (Pinova × Fuji) gave relatively constant and highest yield in the two consecutive years - (49.0 – 49.5%), but it was relatively lower in comparison to those of the standard cultivars Granny Smith and Golden Delicious.

Total sugar content by Brix (%) was almost stable and similar to that of the two control cultivars, but the sugar content in year 2021 was higher than that in 2020. We assume that this was due to the low precipitation, combined with high summer temperatures and insufficient irrigation in 2021.

The total acidity (pH) of the hybrids was almost constant in the two experimental years and was suitable for pasteurization of the juice – pH < 4.5 (Nikolov & Velchev, 2004), except for that of the hybrid 2/17. The values of the Oxidation Reduction Potential (ORP, mV) revealed that the juice produced from the apple hybrids and control cultivars had high oxidation potential and was a suitable nutrient environment for microorganism's growth. After the pasteurization process, the ORP value was reduced at least twice.

Sensory analyzes performed by five specialists using internal laboratory methods showed that almost all tested apple hybrids produced juice with yellow color and its aroma and sweet-sour taste were characteristic for apple fruits. The closest to the control cultivars in this respect was hybrid 4/15 (Pinova × Fuji).

The relative weight respectively the density of the produced juice was high and resembling puree, except for that obtained from hybrids 2/4 and 4/15, which had an appropriate relative weigh, according to the Regulation on the requirements for fruit juices and certain similar products intended for human consumption (Bulgarian State Gazette №100/2013).

The ratio total sugar/pH provides information about juice sensory quality. Altogether, a ratio within the range 3.5–4.5 is preferred as most appropriate in terms of edible quality. Most of the hybrids tested in this study had an appropriate sugar/acid ratio, which resulted in the good sweet-sour taste of the juices (Table 2).

Differences among the studied hybrids and cultivars were observed in the electrical conductivity

Table 2. Technological parameters of the juice, produced from the studied apple hybrids, harvested in 2020 and 2021, t = 20 ± 4°C

Hybrids	Year	Juice Yield, %	Total Sugar (Brix, %)	pH	ORP-Oxidation Reduction Potential, mV	Color*	Relative Weight, mg/l	Aroma*	Taste*	Ratio Total Sugar/pH
№ 6	2020	34.1	12.0	3.7	249	Yellow	1060	1	1	3.2
	2021	34.7	15.0	3.9	277					3.8
№ 9	2020	19.8	14.1	3.3	255	Yellow	1063	1	1	4.2
	2021	36.0	13.0	3.4	360					3.8
№ 152	2020	n.d.	n.d.	n.d	n.d.	n.d.	n.d.	1	1	n.d.
	2021	30.2	17.5	4.8	331	Yellow	1058			3.6
№ 1/3	2020	41.7	15.9	4.0	217	Yellow	1045	1	1	3.9
	2021	38.3	17.2	4.7	305					3.6
№ 1/7	2020	21.2	10.3	2.9	311	Yellow	1067	1	1	3.4
	2021	41.9	17.1	3.4	300					5.0
№ 1/14	2020	8.5	12.8	2.4	237	Yellow	1072	1	1	5.2
	2021	6.0	13.0	3.8	272					3.4
№ 2/4	2020	42.0	13.0	3.0	152	Yellow	1054	1	1	4.3
	2021	33.9	12.4	3.4	341					3.6
№ 2/8	2020	20.0	11.7	3.1	270	Yellow	1069	1	1	3.7
	2021	33.9	12.6	3.7	346					3.4
№ 2/17	2020	25.0	11.3	4.3	336	Yellow	1064	1	1	2.6
	2021	31.6	13.8	5.1	332					2.7
№ 2/28	2020	27.2	11.1	3.0	280	Yellow	1061	1	1	3.7
	2021	29.6	15.3	3.4	362					4.5
№ 2/30	2020	23.0	13.0	3.8	126	Yellow	1068	1	1	3.4
	2021	39.9	15.6	4.4	315					3.5
№ 4/15	2020	49.5	14.0	3.9	109	Yellow	1038	2	2	3.5
	2021	49.0	15.4	4.5	274					3.4
№ 8/22	2020	18.9	13.1	3.1	285	Yellow	1063	1	1	4.2
	2021	34.8	14.3	3.7	302					3.8
G. Delicious	2020	66.5	11.3	3.2	333	Yellow	1034	2	2	3.4
	2021	69.0	18.7	3.6	308					5.1
G. Smith	2020	72.5	11.5	2.9	234	Yellow-Greenish	1031	2	2	3.9
	2021	70.3	15.1	3.5	297					4.3

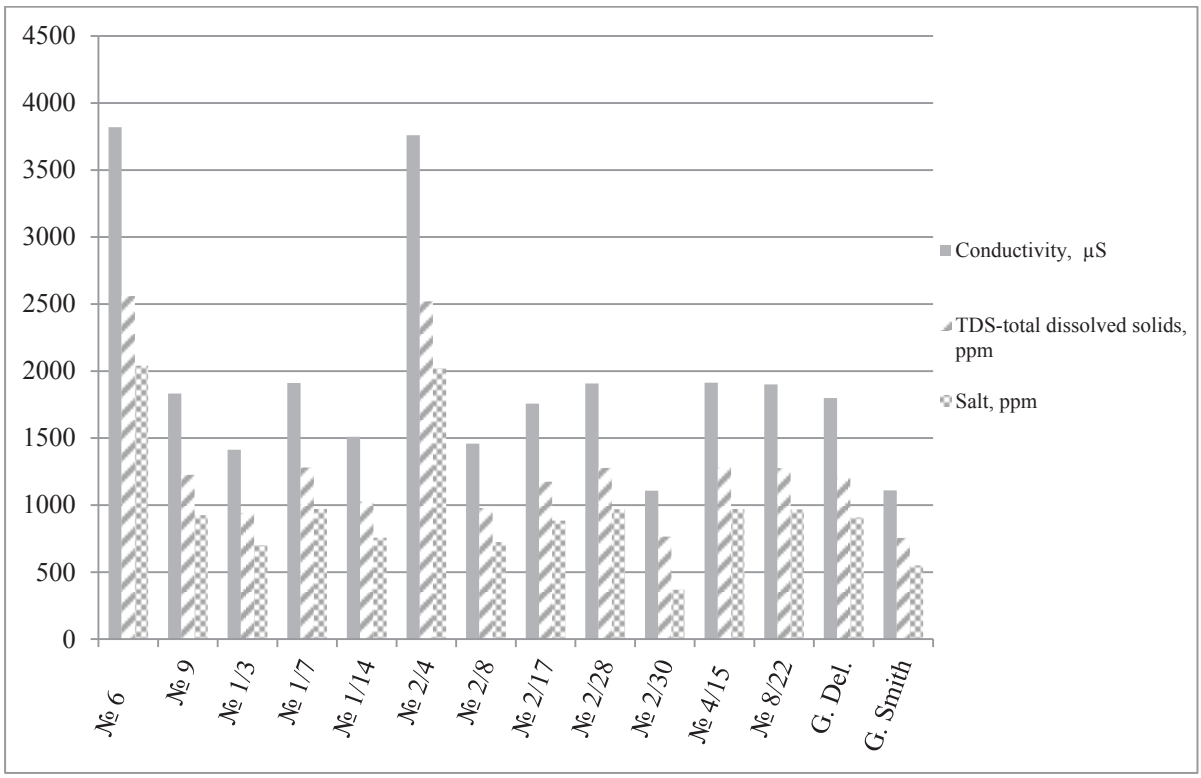
n.d. - no data

*color, aroma and taste are very unstable; the color immediately turned brown and stale due to the oxidation processes;
Aroma*- 1- Typical for apple, without unusual aroma; 2 - Pleasant, typical for apple, without unusual aroma;
Taste* - 1 - Sweet-acid, typical for apple; 2 - Delicious, sweet-acid, typical for apple.

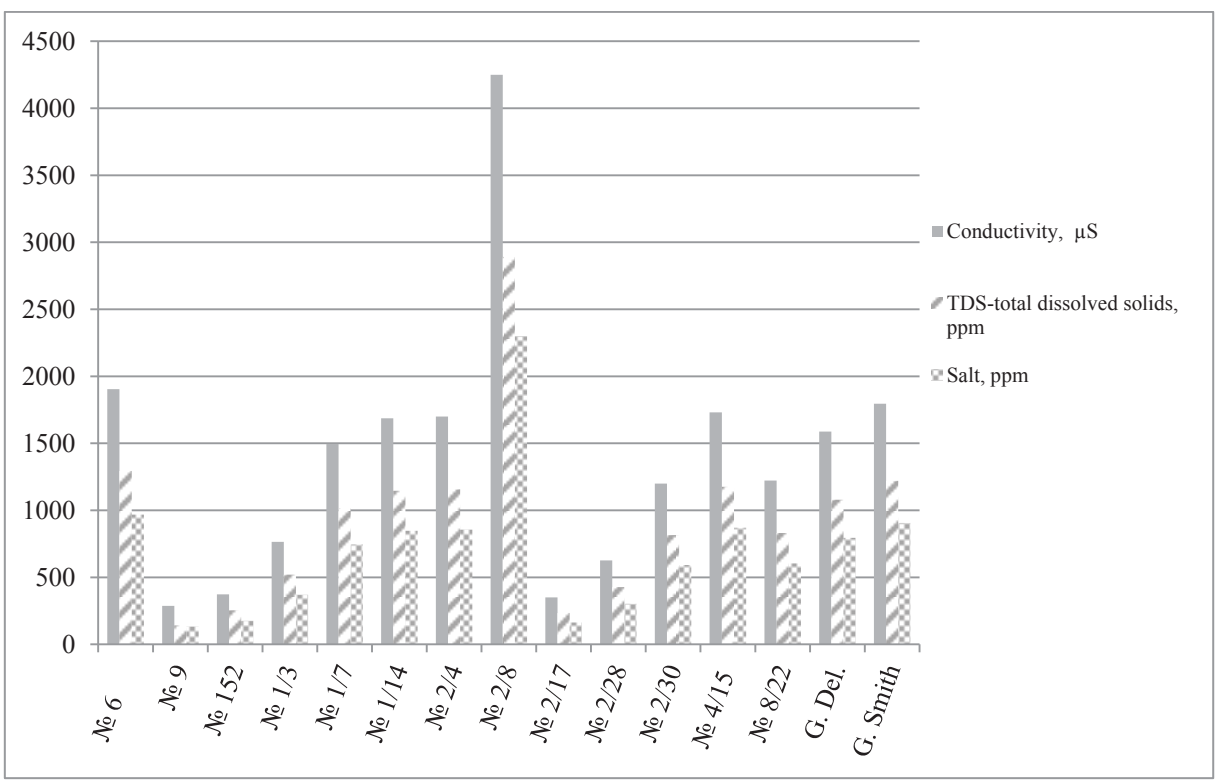
of the juice and its contents of total dissolved solids and salts. Additionally, yearly fluctuations were established in the values of these three parameters (Figure 1 a, b).

The measured values of conductivity, total solute and salt content were significantly lower in 2021, compared to 2020. We attribute this to the weaker movement of water solutions from the roots to the fruit, as a result of reduced soil moisture. During the vegetation period of 2021 the amount of precipitation and irrigation was about twice less. An exception was observed in hybrid 2/8 and Granny Smith, which were not so much affected by the reduced amount of water in the soil.

It was found strong dependence between the conductivity, total dissolved solids and salt content into the juices of apple hybrids. The ratio Conductivity/TDS varied within 1.4–1.5, the ratio TDS/Salt within 1.3–1.4, and the ratio Conductivity/Salt within 1.9–2.0, respectively. These results are in agreement with those obtained for many other apple cul-



a



b

Figure 1. Diagrams of some technological parameters of the apple juice for years 2020 (a) and 2021 (b).

tivars and hybrids grown in the Kyustendil region (Sotirov et al., 2021).

CONCLUSION

Based on the results of the present study, we found that the tested 13 selections of apples in terms of their cropping performance and fruit quality traits (size, weight, flesh firmness, appearance, taste, etc.) are not inferior to the standard cultivars Golden Delicious and Granny Smith. We determined № 8/22, 9, 4/15 and 2/28 as the most suitable for commercial cultivation for fresh consumption of fruits. The overall data of these hybrids indicate they are promising cultivar candidates. The hybrids 2/4 and 4/15 were the most appropriate for the production of apple juice by cold pressing; they produced juice with excellent taste and organoleptic qualities, color and aroma. Furthermore, they have a high juice yielding potential, and thus their juice can be produced without mixing with fruits of other cultivars, hybrids, or species. The quality of juice of hybrid 4/15 can be defined as premium or luxury. However, no juice was produced from hybrid 1/14 but a pulp-like suspension (puree) by cold pressing of its fruits. The rest of the examined hybrids can be used for production of fruit juice by the cold pressing method, but together with fruits of other apple cultivars or other species with high juice-yielding potential. This study was conducted in only two seasons. Thus, further investigations are required of the tested and other apple hybrids and cultivars to better understand the influence of their specific physiological and biochemical fruit parameters as well as organoleptic indicators on apple juice quality.

ACKNOWLEDGEMENTS

The research performed and the publication of this paper were supported by the Bulgarian Ministry of Education and Science (Fund "Scientific Research") – Project "Breeding and application on new yellow-green crisp apple in Bulgaria and China" – Contract № KP-06-China /4 from 20.12.2018.

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